SEMINAR PROCEEDINGS

PRACTICAL IMPLEMENTATION OF STORM WATER MANAGEMENT TECHNIQUE

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OPENING COMMENTS

PRACTICAL IMPLEMENTATION OF STORM WATER MANAGEMENT TECHNIQUES

Monday, October 20, 1980
Skyline Hotel, Etobicoke
W.J. Warwick, P. Eng.

First of all, let me tell you how glad I am to be here this morning. I must, on behalf of the M.O.E. and M.E.A., extend to each and every one of you a warm welcome, and our appreciation of your support of this seminar.

As a practicing municipal engineer, I am not very interested in the complexities of Storm Water Management as far as modeling, computer programs, and the finite theory go. But I am extremely interested, and feel sure that many of you share the view, that what we want to know is what can be done in Ontario to implement the new and modern concept of Storm Water Management. I leave it to academics and others to make the computer work for me, and not me work for the computer.

Storm Water Management is the "in thing" of the early '80's' on the subject.

For the next two days, you will be attending sessions on policy and planning from both provincial and municipal points of view. There are also technical sessions to provide you with an overview on design technique, erosion control, and legal aspects of drainage. Tomorrow afternoon we will distribute a questionnaire, which we ask you to complete. It is a very simple questionnaire in which we seek your views on the value of this seminar.

What is Storm Water Management? I do not accept that this is something really new. The name is, and I like the way it sounds. It means something more positive to all of us. It tells us to recognize and consider all components of the storm sewer system from the upper reaches of the watershed through the system, and, finally, to the eventual receiving waters. Various rainfall events are included during the design process to identify their effect on the watershed. Simply stated, it is the planning, analysis, and control of storm water runoff to meet specific objectives. Storm water facilities must be planned to co-ordinate with flood plain

land use, and other servicing plans.

Historically, the conventional or convenience system would size storm sewers to accommodate the flow from a storm intensity predicted to return once every 2, 5, or 10 years (or such other period chosen by the designer). However, we all know that storms of greater intensity do occur, and cause flooding and property damage. These events occur so infrequently that to design the convenience system to the greater intensity storm is considered economically unjustifiable. In addition to this, very little, if any, provision was made for overland flow routes to accommodate flows over the design return periods, or to provide effective control over building elevations to limit backups.

It must be realized that the overland flow route, or major system, will exist in a serviced community, whether or not it has been planned or designed, and whether or not development has been wisely situated with respect to it. Water will obey the law of gravity, and flow downhill to seek its lowest level, whether buildings or people are in its way or not.

Emphasis must, therefore, be placed on early and thorough planning, not only within the major pieces of legislation, but also within the small-scale subdivision work. To do this, an educational program to reach land use planners, architects, developers, politicians, and the general public, is essential. How this will occur, if ever, I do not know, but it is essential for the successful implementation and acceptance of Storm Water Management. There are many opportunities to achieve storage and detention of storm water if the concepts are applied at an early stage in the planning process. For instance, the siting of parks, schools, and open space areas can provide the dual purpose of storm water control and recreational activities, if well placed by the town planners and development planners. Also, the location of roads can act against overland flow routes by forming a dam, or act with them by providing a natural flow path.

Another aspect of Storm Water Management which I would like to briefly touch on is that of quality of storm water. Up to now, this has been given a lower priority of consideration, as we have primarily tackled the problems inherent in the quantity part

of Storm Water Management, probably because it is the easier of the two, at least in my opinion it is. Water quality control measures will be given due consideration as we go through the '80's'. Detention systems can only help us in this. I do not believe that quality control is a problem of what could be done, but what should be done. This was inherent in the thinking of the Steering Committee in the planning of this seminar. This, to my mind, is what a design engineer wants to know. What should be done now to continue, or, in some areas, to commence the practical implementation of Storm Water Management techniques?

URBAN DRAINAGE POLICY DEVELOPMENT IN ONTARIO

D.G. Weatherbe[1]

BACKGROUND TO POLICY PROPOSALS

Introduction

In keeping with the theme of the symposium session - Influence of Man - our goal as scientists and environmentalists should be to seek to minimize the influence of man on the hydrology and water quality of the environment. We should not just record and observe the changes caused by man on the environment. Of course, to do this we have to proceed through the technical and scientific steps of: first, recording the influence of man to identify the presence of problems; second, developing special methods for analysing the problems and predicting future problems; third, developing technical solutions for resolving problems which can be tested with the analytical tools; last, an implementation program to allow application of technical solutions in the jurisdiction of concern should be developed. This process is being followed in Ontario and this paper will provide an outline of the background technical studies and a status report of the development and application of urban drainage policy.

Non-point sources have been identified by the International Joint Commission (IJC) as significant contributors to the worsening of the water quality in the Great Lakes. The recommendations of the IJC in the early 1970's led to the establishment of two research programs dealing with non-point sources. The first program dealt with various point and non-point sources related to land use and was carried out by the Pollution from Land Use Activities Reference Group (PLUARG). The second program was administered by the Urban Drainage Sub-committee.

PLUARG Studies

The Canada-U.S. Agreement on Great Lakes Water Quality of 1972 led to the study of pollution in the boundary waters of the Great Lakes system from land use activities. Past studies indicated that current conditions in the lakes could not be related entirely to readily identifiable point sources. In order to quantify and describe non-point sources of pollution, PLUARG studied the pollution potential of several land use activities, including agricultural, urban, forestry, transportation and waste disposal activities, as well as natural processes such as lakeshore and river bank erosion. PLUARG also examined atmospheric deposition of material on land and water surfaces.

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On a lake-wide basis, the major problems were considered to be eutrophication or accelerated aging of the lakes, and the buildup of toxic substances in the lakes. The study found that the Great Lakes are being polluted from drainage sources by phosphorus, sediments, some industrial organic compounds, some previously used pesticides, mercury and, potentially, other heavy metals. Local problems in some nearshore areas are associated with sediments and microorganisms in land drainage. Combined sewer overflows were recognized to cause increased loadings of most pollutants and elevated microorganism levels in local receiving waters.

Recommendations in the PLUARG report to the IJC (1) included the development and implementation of management plans to reduce the loadings of phosphorus, sediments and toxic substances from rural and urban areas. It was recommended that the management plan for urban areas include:

i) proper design of urban stormwater systems in developing areas such that natural streamflow characteristics are maintained;

ii) provisions for sediment control in developing areas; and

iii) control of toxic substances from commercial and industrial areas.

The IJC in its report on the PLUARG findings to the governments of the United States and Canada stated "the major problems of urban non-point pollution, with the exception of combined sewer overflows, relate to the control of sediment and associated pollutants. To a large degree these problems can be prevented or alleviated by greater awareness, planning and proper design of urban developments and infrastructure. The preventative approach should be universally adopted for new urban development. Application of structural remedies to existing urban areas will be extensive and more difficult to achieve, and should be assessed on a case by case basis". They further suggest in the report that the technique mentioned above for urban management plans be utilized as well as methods such as street sweeping for control of pollutants at source in developed areas (2).

Urban Drainage Sub-committee Studies

The government of Canada and the Province of Ontario entered into an agreement in 1971 - the Canada-Ontario Agreement on Great Lakes Water Quality - to accelerate the abatement of pollution in the lower Great Lakes. As part of this agreement, the Urban Drainage Sub-committee (UDS) was formed, with terms of reference:

i) to define the magnitude of pollution due to urban runoff in the Great Lakes Basin;
ii) to develop or recommend appropriate analytical and control technology for resolving problems; and
iii) to develop a strategy for implementing solutions to the problem.

Studies addressed each of the terms of reference in separate phases. It was concluded from a number of monitoring studies in the first phase that urban runoff is a significant source of pollution, particularly in the case of combined sewer overflows (3, 4, 5, 6, 7, 8, 9). Two studies which addressed the overall magnitude and significance of loadings to the Great Lakes from urban runoff aided in the assessment of the problem (10, 11). It became apparent that pollution control of urban runoff could not be considered without also considering flood control, since municipalities and property owners are most concerned with basement and surface flooding, and both types of flooding occur relatively frequently (12, 13). It also became clear that the urbanization effect of increasing both the rate and volume of runoff water discharged to receiving streams often resulted in water quality degradation, flooding and channel erosion.

The second phase of the study led to the review of urban runoff models and the acquisition of considerable experience in the use of these models, notably the U.S. Environmental Protection Agency's Storm Water Management Model (SWMM) and the U.S. Army Corps of Engineer's Storage Treatment Overflow Runoff Model (STORM) (14). Several studies reviewed preventative and remedial measures such as stormwater management ponds (15, 16), and other control technologies described in the UDS summary report (17). Much of the work carried out in the United States proved helpful in identifying useful technologies and avoiding duplication of effort (18).

The third phase of the program which dealt with development of a strategy for implementing solutions, led to a series of conferences and publications, with the goal of transferring information and knowledge gained in the program to potential users - primarily municipalities and consulting engineers (19, 20, 21). The Urban Drainage Manual of Practice (22) which provided an overview of urban drainage problems and solutions was developed. Also as part of this phase, a committee - the Urban Drainage Policy Committee - was formed to consolidate all the research and development findings and propose comprehensive model policies for urban drainage management which would lead to the alleviation of pollution as well as the resolution of flooding problems in urban areas. The model policies to be developed were to take account of the administrative and legislative framework in Ontario such that the policies could subsequently be considered for adoption by the Ontario government. These model policies could also form the basis of urban drainage management programs for other jurisdictions; however, the legislative and administrative framework in other jurisdicitions would have to be taken into account. The following section of this paper is summarized from the report of this committee (23).

PROPOSED URBAN DRAINAGE POLICIES

Policy Objectives

The various levels of government have the common goals of preserving and improving the quality of the environment for present and future

uses, protecting life and property from damages, conserving natural resources, and maintaining and upgrading the standard of living, as well as supporting orderly development. In terms of urban drainage management, these goals can be translated into the following specific objectives:

- to prevent health hazards, loss of life and property damage on site;
- to minimize inconvenience from surface ponding and flooding on site;
- to minimize alteration of the local groundwater system and the hydrology of receiving watercourses;
- to minimize downstream flooding, changes in natural stream geometry and channel erosion;
- to minimize pollution discharges to watercourses; and
- to minimize sediment pollution of watercourses from construction activity.

In meeting these objectives, costs should be minimized and the rights of riparian owners should be maintained where these rights have not been specifically set aside by legislation.

Modern Concepts in Urban Drainage

In order to fulfill the objectives stated above and avoid the past problems and expenditures to remedy these problems, a new approach to urban drainage management was considered necessary by the policy committee. This new approach consists of the application of new and existing urban drainage concepts through a broader use of existing planning mechanisms, using new and innovative technology where needed. Proper planning of urban drainage systems must consider the use of the natural drainage system with the goal of retention of the pre-development runoff hydrograph. Other important concepts for urban drainage include the use of the watershed as the logical unit for drainage planning, the recognition of the dual role of the major and minor drainage systems, and recognition of the necessity of cost-effectiveness in drainage and environmental planning. The existing framework for land use, environmental and drainage planning can be utilized to apply these concepts, which are described in more detail below.

i) The natural drainage system concept requires recognition of the natural or predevelopment hydrologic cycle and an attempt to maintain this natural cycle in an urban development, by a combination of planning and structural and non-structural measures. The effect of adopting and applying this concept to drainage design is to minimize the long-term negative effects of new developments such as flooding downstream, channel erosion, and water quality degradation (24). Methods of applying this concept include protection of natural watercourses where possible by maintaining their natural state, maintenance of pervious surfaces by discharge of roof drainage onto grass surfaces in low to medium density developments, use of waterways where practical to retard surface runoff rates and

allow for increased percolation of runoff, retention and detention of stormwater on rooftops, parking lots, and stormwater management ponds and in sub-surface storage areas.

ii) The concept of watershed planning is well recognized; however, in practice little urban drainage design is based on this concept. The watershed is the natural system for conveyance of runoff during storm events and is also the system for conveyance and assimilation of natural and man-made wastes. Master drainage planning on a watershed basis prior to land development is required to properly recognize this in drainage planning and design.

iii) The concept of the major and minor drainage system should be recognized in the design of drainage elements for new urban development and in the design of remedial measures. The minor or convenience system consists of roof drains, gutters, catch basins, storm sewers and channels, typically designed to accept runoff from a typical "design storm" with a frequency of occurrence of from 2 to 10 years. The major system is the route followed by runoff waters when the capacity of the minor system is exceeded which when recognized in design, consists of roadways, drainage easements and storage ponds (if required) and major watercourses. If the major system is not recognized in design of urban drainage systems then surface flooding, surcharged storm sewers and severe property damage may result whenever the minor system capacity is exceeded (24).

iv) The concept of economic efficiency or cost-effectiveness should be considered in drainage design and pollution control planning in wider scope studies which allow proper consideration of benefits and costs, and which allow more alternatives to be considered in the planning stages.

Administrative Considerations

Land use planning is typically carried out by municipalities, with the Planning Act (25) providing the means for municipalities to set up "official plans" for the purposes of providing for "the health, safety, convenience and welfare of present and future inhabitants". Environmental planning is carried out under the auspices of the Ministry of the Environment as set out in the Ontario Water Resources Act, the Environmental Protection Act and the Environmental Assessment Act (26, 27, 28). Flood control planning is carried out by conservation authorities under the Conservation Authorities Act (29) administered by the Ministry of Natural Resources. This Act also provides a broad legislative mandate for a conservation authority to manage the renewable natural resources of a watershed.

It was concluded by the Urban Drainage Policy Committee that adequate planning procedures were available for implementation of urban drainage policies and that legislation was in place to support any proposed policies. As described previously it was also

considered that the technologies for analysis of urban drainage systems and control of urban runoff were available and thus that there was no technical limitation for implementing proposed policies.

Proposed Policies

The proposed policies address the environmental, property protection and economic efficiency objectives of drainage design, and call for comprehensive planning to be adopted to implement the objectives. The proposed policies cover five specific areas as described below.

i) Municipalities, in co-ordination with conservation authorities, would be required to develop master drainage plans for all watersheds within their boundaries. The purpose of this policy is to foster master drainage planning for rapidly developing municipalities to ensure that stormwater drainage systems are developed in a manner compatible with watershed needs, to identify existing water quality and flooding problems and to avoid future problems.

ii) Municipalities with sewage collection and treatment systems would be required to formulate and implement a comprehensive pollution control strategy which includes consideration of both wet and dry weather pollution sources. The initial stage of the formulation - an in-system review of the relatively unknown wet weather sources, volumes and magnitudes of pollution - would be required as a basis for plan formulation. Consideration of receiving water objectives and the cost and effectiveness of wet weather versus dry weather controls would lead to a final comprehensive strategy. The end result is felt to be a more cost-effective investment in municipal pollution control.

iii) New drainage systems for all development would be required to be designed using the major-minor system concept which recognizes the dual role of the drainage system in providing for convenience during minor (high frequency) runoff events and to minimize property damage and protect life during major (rare) runoff events. Expenditures for sewer construction are expected to be reduced since the minor system would be designed to avoid excessive cost through the use of overly conservative design techniques or excessively rare design storms, bearing in mind that the major system would be designed to provide protection against damage from storms which exceed the capacity of the minor system. The overall drainage system would provide a higher level of protection since the major system of flow routes on roadways and drainage easements would be designed for rare events and would also recognize that some level of inconvenience would be experienced from time to time.

For residential areas, a design frequency as low as a one and two year storm should be considered for minor system design. The major system should provide the same level of protection as is provided by floodplain management programs, which in Ontario is protection from a one in one hundred year storm occurrence.

iv) Components of new urban developments would be required to indicate the effects of the development on a watershed and to carry out mitigative measures as required. Hydrologic changes and pollutional effects on the receiving water course are considered to be the important effects in this case. This policy is best carried out in relation to an existing master drainage plan, in which case the specific requirements for new urban developments would already be addressed in a general sense by the master drainage plan. In the absence of master drainage plans, this policy would require some consideration of watershed effects; however, not to an excessive level of detail.

V) Proponents of new urban developments would be required to plan for and carry out an erosion and sediment control program in the planning and construction stages of development, and to follow this up with an adequate maintenance program. It is felt that construction generated sediment pollution is a severe enough problem to justify controls on an across-the-board basis.

IMPLEMENTATION

Concerns Expressed

The report "Proposed Model Policies for Urban Drainage Management" (23) was circulated in 1979 to provincial and federal government agencies, municipal and consulting engineering organizations, and the development industry. Generally the proposals were received favourably with only minor modifications of the proposals requested; however, some concerns were expressed regarding future implementation programs. It was pointed out that an adequate technical capability was needed by those involved in planning, designing, reviewing, approving and operating urban drainage systems using new technology and concepts. Consequently, a broader based and continuing training program would be needed to implement the policies. The jurisdiction for implementation of the proposed policies at various levels of government needed further clarification, and the review and approval procedure needed to be spelled out in detail. Municipal officials pointed out the need for subsidies and grants for engineering studies and capital works. Detailed technical guidelines for each policy area would be required. The need for a follow-up implementation committee was pointed out and this is recognized by the Ontario government.

Implementation Committee

An implementation committee is proposed to start in 1980 to take account of the concerns expressed in the review of the proposed policies. The implementation committee will adapt and refine the model policies, taking account of recent administrative and legislative changes in Ontario. A detailed implementation package will be prepared outlining administrative arrangements, available and needed resources for implementing the policies, technical

guidelines such as an Ontario "Code of Drainage Practice", and a phase-in program for implementing policies. An impact statement outlining the effect the policies would have on the financial and human resources of the province will be prepared.

Application Example

As described above the policy proposals have been circulated widely and the concepts presented in a number of forums. Consequently, several Ontario cities have adopted most of the policies on the basis of their underlying logic and the benefits to be achieved from implementing them. A notable example is the City of Oakville which has set the following objectives for urban drainage management:

i) to ensure that the constraints and opportunities associated with urban drainage are properly recognized and are integrated with community plans and designs;

ii) to reduce, to acceptable levels, the potential risk of health hazards, loss of life and property damage from flooding;

iii) to reduce, to acceptable levels, the incidence of inconvenience caused by surface ponding and flooding;

iv) to ensure that any development or redevelopment is effected so as to minimize the impact of change to the groundwater regime, increased pollution, increased erosion or increased sediment transport, especially during construction; and

v) to maintain the natural stream channel geometry, insofar as it is feasible while achieving the above objectives.

The report outlining the Oakville policies (30) also presents details of major and minor system design, planning approaches to urban drainage, erosion control criteria, requirements for master drainage plans and computational methods for aid and design.

ACKNOWLEDGEMENTS

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Development of Municipal Drainage Policies

O. H. Ellis, P. Eng.

By adopting storm water management techniques, past problems, some with expensive engineering solutions, are being avoided and superior communities are being developed. This paper explains how one Ontario town, Oakville, developed its drainage policies and elaborates on these policies and certain problems associated therewith.

O. H. (Hal) Ellis, P. Eng., graduated from Queen's University, Kingston, Ontario with a B.Sc. in Civil Engineering in 1957. Following graduation, he was employed by Metro Toronto Roads Dept. until 1963 when he joined the Town of Oakville where he has held various positions. He became Director of Public Works in 1976. He is married and has three children.

I. INTRODUCTION

Houses in flood plains, expensive dams and diversion channels, concrete lined ditches, natural creeks piped and lost forever, flooding in basements, flooding on roads, erosion of creek valleys - sound familiar? These are the result of a lack of adequate storm water management policies in the past. Fortunately, lessons have been learned and attitudes are changing. Today, at all levels of government, we are working very hard to avoid the types of problems referred to above.

As of two years ago, our storm water management policies in Oakville were very short and simple - Use the Rational Method with a 10 year curve and keep the houses out of the flood plains. Drainage was not considered at the time of community planning but after the fact. However, several large communities were being proposed for Oakville which would double our present population of 70,000 over the next 20 years. Some of this development would involve massive engineering works like diversion channels, dams, and channel improvements if we proceeded as in the past while other developments threatened the future of some of our smaller creeks. We were aware that there were alternative procedures available such as controlling run-off which would avoid these expensive engineering works. Also, we were aware of some of the other storm water management techniques being used in the U.S. and Canada. The Provincial Ministries were looking at storm water management policies and guidelines but progress seemed slow and it was not known when they would be implemented nor how they would affect us. It seemed that the time had arrived that we should proceed to prepare our own policies for use in the development of these new proposed communities and to whatever extent possible in the existing developed areas of the Town. These policies would then be used until the Provincial Ministries implemented theirs, at which time ours would be altered as required. The Town, therefore, utilized the Consulting Engineering firm of Andrew Brodie Associates Inc. who were made available at the expense of one of the major developers, Genstar Limited, to work with its Technical Co-Ordinating Committee in the preparation of a new Storm Drainage Policies and Criteria manual. The Technical Co-Ordinating Committee was composed of representatives from Halton Region Conservation Authority and the Town of Oakville's Departments of Planning, Building and Public Works. Consultations with Parks Dept. officials were made regarding

certain aspects of the policies. We decided to have every group represented who was involved in storm drainage in any way and to try to incorporate their concerns and comments. In this way, when we were finished, we would have policies which we could all support and carry out in our respective departments. We believe we accomplished this. We did not set out to re-invent the wheel. We did no original research. We looked at manuals, guidelines, and practices from other places in Canada and U.S., relied on the expertise and experience of our consultants and tried to use some common sense of our own. We adopted what we felt should be good for the Oakville situation. We hope that we have practical policies and criteria but only time will tell. The manual was completed just over a year ago so we have not had much practical experience to date that we can share with you. Our staff have just barely got their feet wet in applying these policies and in dealing with consultants on the various computer models available. We have a long way to go yet. Storm water management is a rapidly advancing field at the present time so we will undoubtedly have to update the manual in the future in keeping with the latest techniques, information, and requirements. Oakville Town Council in September 1979 adopted the new Storm Drainage Policies and Criteria as contained in the Manual for future use in Oakville and no changes are to be made to these policies without Council's approval.

II. OBJECTIVES

Our five objectives for urban storm drainage management in Oakville, quoted directly from the Manual, are as follows:

1. Ensure that the constraints and opportunities associated with urban drainage are properly recognized and are integrated into the community plans and designs.
2. Reduce, to acceptable levels, the potential risk of health hazards, loss of life and property damage from flooding.
3. Reduce, to acceptable levels, the incidence of inconvenience caused by surface ponding and flooding.
4. Ensure that any development is effected so as to minimize the impact of change to the ground water regime, increased pollution, increased erosion or

increased sediment transport, especially during construction.

5. Maintain the natural stream channel geometry, insofar as it is feasible while achieving the above objectives.

III. MAIN POLICIES

The main policies which we have adopted are in keeping with Provincial policy proposals and are:Major and Minor Systems, Planning for Storm Drainage, Master Drainage Plans, Control of Runoff, and Natural State of Watercourses. We will discuss these now in a general sense before returning to discuss some of the policies in more detail later.

1. Major and Minor Systems

The urban drainage system is divided into two separate and distinct components called the "minor drainage system" and "the major drainage system". The minor drainage system comprises street gutters, catchbasins, and storm sewers and accommodates the runoff from the more frequent storms up to the design capacity of the system. It reduces the inconvenience to pedestrians, mororists, and residents due to runoff and as such is sometimes also called the "convenience system". The major drainage system comprises the natural streams and valleys and the man made channels and ponds. The streets also are components of the major drainage system during severe floods when they must transport the runoff in excess of the storm sewer system capacity (minor drainage system). The runoff in excess of the capacity of the minor drainage system is known as "overland flow". The streets must be designed in such a way as to transport overland flow along downgrades throughout its journey to the exits into the streams and channels without encountering sags. The major drainage system is the keystone to good urban drainage since it should accommodate the runoff from even the least frequent storms such as once in a hundred years and the Regional Storm. Properly designed and constructed, the major system will essentially eliminate the risk of loss of life and property damage due to flooding. The floodplains on those portions of creeks draining over 130 hectares (1/2 sq. mile) have

been adequately protected in recent subdivisions by the Conservation Authorities. However, under our new policies providing for overland flow over our streets, buildings along these streets will now also be protected from storms up to once in one hundred years. This is an important improvement over our old system where there was no provision for overland flow and sags in streets were common.

2. Planning for Storm Drainage

(a) General Approach

The general approach of the Town in planning new communities will be to integrate the needs for land use with its needs for drainage and in accordance with the regulations of the Conservation Authorities and the Provincial Ministries. Drainage needs must be recognized from the very start and not superimposed on a development after the layout has been approved.

(b) Blue-Green Concept

The Blue-Green Concept is the term commonly used to describe the integration of the open spaces provided by Hazard Lands, major drainage systems, stream valleys and parks into a continuous green belt that serves the dual purposes of recreation and water management. We have approved plans for the design of a pathway system, benches, and landscaping through or beside the creek valleys in one proposed community to date and will require similar integration where feasible, in all future ones.

(c) Master Drainage Plans

A Master Drainage Plan is a plan of watershed, or group of watersheds, that sets out the Municipality's intent. It is not part of the Official Plan but it will be used to guide development or redevelopment in that watershed. Eventually, we intend to prepare Master Drainage Plans for each watershed within the Town. The Master Drainage Plan delineates watersheds and floodplains, indicates constraints associated with water quality and quantity, indicates existing erosion or bank instability problems and their solutions, and indicates specific flood control and environmental requirements for the watershed.

The Town has completed one Master Drainage Plan to date and has commenced work on another.

3. Control of Runoff

(a) Runoff Quantity Control

Urbanization increases the rate and amount of runoff from any given storm due to the increase in imperviousness. These cause higher flood levels and increased erosion. Therefore, the Town requires control over the quantity of urban runoff. The degree of quantity control will be determined by the Master Drainage Plan. Where a Master Drainage Plan is not yet prepared, no increase in post-development peak flow will be allowed over the corresponding pre-development peak flow for all levels of storms up to the 1/100 year storm. In certain cases, development in the past has been allowed to encroach upon the watercourse downstream of the proposed development. The Town, in conjunction with the Conservation Authorities, has been working at reducing the incidence of potential property damage from flooding with such remedial measures as are practical and financially justifiable. With the future development of upstream communities, opportunities may become available to exercise over-control and thus alleviate the problem downstream with a preferred solution.

(b) Runoff Quality Control

The most noticeable degradation of water quality in the past has been during construction. The Town therefore requires developers, contractors, and builders to plan and execute their operations so as to minimize sediment and debris pickup and transport to water bodies. The degree of control and methods used must meet the regulations of the Conservation Authority as well as the Town. We recognize that there are certain positive features of the "wet pond" or retention pond, one of them being to provide a settling basin for sediment and certain pollutants in storm drainage and thus improve water quality downstream. However, we have concerns about other aspects of wet ponds, particularly the smaller ones (under 2 hectares). While we do not rule them out, proponents of a wet pond will have to prove that it will be a benefit and an asset to the community, will create no health or safety hazard and can be maintained in an aesthetic condition.

4. Natural State of Ravines

We consider our ravines to be valuable natural resources worthy of being preserved. It is our policy that major system watercourses and their valleys are to be left as much as possible in their natural state. Realignments, diversions, and deepenings from the natural state will not be permitted unless they can be proven to be necessary both to the Town and the Conservation Authority. All streams are to be named and their names posted on signboards at major road crossings.

IV. POLICY DETAILS

A. Major Drainage System

(1) Hazard Lands and Floodlines

The Conservation Authorities already have regulations governing the construction of buildings and structures within the floodplains of Regional Storms and governing the placement of fill in any area which may affect flooding, pollution, or conservation of land. These regulations,in practice, are only being applied to watercourses below the point where the watershed area being drained is 130 hectares. The Town requires that the floodplains that would result from the 1/25 year, 1/100 year, and Regional Storms be defined for pre-developed conditions and for post-developed conditions with control. This is to apply to the area to be developed as well as watercourses affected downstream of development. Where a natural watercourse or man-made channel is used as part of the major drainage system in a new development, irrespective of the drainage area, the Town requires that all land that would be inundated by the greater of the Regional Storm or 1/100 year storm floods be classified as Hazard Land.

(2) Acceptabliity of Floodproofing

Floodlines of a Regional Storm on most Oakville watercourses will usually fall within tops of banks of a definite valley. Where this is not the case and the depth of flooding on the "flood fringe" due to a Regional Storm is less than one metre outside of the definite valley, the Town may consider an application for development. The developer would also require a permit from the Conservation Authority. Any development permitted would require floodproofing and the proponent would have to demonstrate that the development would not suffer unacceptable damage and that it would not create

an environmental hazard. Day time parking may also be considered in the flood fringe under certain conditions.

(3) Methods of Quantity Control of Runoff

Runoff may be controlled in many ways such as:

a) Discharging rainwater leaders onto grassed areas.
b) Temporarily storing water on flat roofs and parking lots.
c) Using grassed swales and ditches rather than pipes.
d) Using roadside ditches where feasible.
e) Storing water underground in tanks or superpipes and using a restricted outlet.
f) Diverting overland flow into temporary detention ponds located in parks and highway interchanges with discharge limited to some predetermined rate.
g) Constructing temporary detention storage facilities on the major system watercourse with discharge rates being controlled.

The Town endorses the use of any or all of these methods for controlling the rate of runoff from a proposed new community or for redevelopment within the existing urban area. Rainwater leaders are to discharge onto grassed areas with splash pads on all medium and low density residential lots having frontages over 13.5 metres and with split drainage. With drainage all to the front and the distance between units at least 3.5 metres, this is also a requirement. Similarly, wherever possible on industrial and institutional lots, leaders are to discharge onto grassed areas. When this is done, the imperviousness of the roof surfaces can be neglected in calculating runoff. Temporarily storing water on rooms of industries and stores equipped with slow discharge roof hoppers can be effective providing you have the full cooperation of the private owners. You may require these controls under Section 35a of the Planning Act and you may enter into a Site Plan Agreement that the owners will maintain these adequately and not remove them. However, who is going to enforce these agreements over the years and how? When these controls are placed on private property you cannot count on them not being tampered with or removed sometime, either innocently or deliberately. Where there is a restricted flow pipe running from private property, where there is a considerable area involved, into the public storm sewer, it would

be advisable to have a manhole at the street line with a publicly owned line out to the storm sewer.

We did not think it possible to revert back to roadside ditches in our new residential subdivisions but where possible in the future some of our arterial and collector streets with reverse frontage lots will be constructed using rural sections. Consideration will also be given to constructing some of our industrial streets in the future using rural sections. When a park is used for a temporary detention pond proper caution notices should be posted and maintained to ensure the safety of the park users.

Detention ponds (dry ponds) located on watercourses seem to us to be one of the best methods of controlling runoff from new development. While they do not assist in minimizing increase in total volume due to urbanization, they are excellent devices to attenuate peak rates of runoff and release the water at or below pre-development rates. They are entirely under the ownership, control, and maintenance of the municipality so that their continuance as storm water management facilities as intended is insured. You will just have to make sure that your maintenance forces make no alterations to the dry pond or to the control structures without prior approval of the engineering section. Wherever possible, the dams and control structures for these ponds should be incorporated into a road crossing of the watercourse valley. Road crossings of these watercourses should be limited to arterial and collector roads. If the dam or combination road/dam will be topped by a less frequent flood, say from a Regional Storm, the surface should be protected by paving or interlocking stones to prevent washout. The outlet structure should be designed with ease of operation and maintenance in mind. It should be of the free-flow ungated type without valves or stoplogs. Inlets and outlets should be protected to prevent child access.

4. Methods of Quality Control of Runoff

Urbanization of an agricultural area results in an increase in sediment and debris transport during construction but a reduction in sediment transport after the whole urban area is established. Nevertheless, the sediment and debris from an urban area is still undesirably high, particularly since it also contains other pollutants.

By using improved street cleaning techniques including vacuum equipment and more frequent catchbasin cleanings, the pollutant loading on the watercourses can be reduced. Reduction in the quantity of de-icing salt used in the winter on our street will also assist. The major problem remains that due to construction. The Town requires the proponent to submit an outline of his proposed erosion-sediment control plan with his initial servicing report. This may contain any or all of the following measures - sediment traps, straw bale weirs, temporary retention ponds, seeding of topsoil stock piles, berms around stock piles, vegetation screens, and sequential stripping of lands. Frequent inspection and any required maintenance and repairs to these control works throughout the course of construction is very important.

5. Watercourse Erosion and Bank Instability

We require the developer to identify areas of existing erosion or bank instability in the area he intends to develop and to propose his intended remedial measures to us for our consideration and approval. These proposed measures also require the approval of the Conservation Authority. Where an upstream development will cause significantly increased downstream erosion, we will require the developer to obviate further damage by appropriate remedial measures. Natural valley aesthetics as well as a sound technical solution must be considered in designing remedial erosion and bank instability works. A normal low water channel has a capacity of about the 1/5 year storm flood. Protection to this level is adequate to us provided that the channel bank is not coincident with a higher valley bank, in which case it may be necessary to protect the bank to a level as high as the flood resulting from the Regional Storm.

B. Minor Drainage System

1. Hydraulic Design Levels

We require the system of street gutters, catchbasins, and storm sewers to be designed to accommodate the 1/5 year storm with the following two exceptions:

a) Consideration will be given to using a 1/2 year storm in low to medium density residential development, if required to achieve a specified degree of quantity control for the community.

b) A 1/10 year storm will be used for downtown business areas and other high value commercial development. In such cases, we may require some internal control in the form of roof storage, temporary storage on parking areas farthest away from the buildings or underground storage.

It is imperative that the interception capacity of the catchbasins not exceed the design capacity of the storm sewers to prevent surcharging of the storm sewers. This can be achieved by varying the spacing of catchbasins and/or installing inlet control devices on them such as orifice plates. In this way, surcharge of the storm sewers will be prevented and basements will be adequately protected against backflow through the weepers. We have had no orifice plates required to date but some will be required in an upcoming subdivision. Maintenance foremen and workers have to be clearly instructed not to remove any orifice plates or add additional catchbasins which could surcharge the storm sewers. Any suggested changes to the drainage system will have to be checked out first with the Engineering Section.

2. Connection of Weepers

Weepers is the term commonly used for weeping tile drains which are foundation drains. We connect weepers by gravity to the storm sewer system provided the elevation of the basement floor is at least 0.60 metres above the elevation of the storm sewer obvert at that point. For buildings located close to where the storm sewer discharges into the major system, there is the additional requirement that the basement floor elevation must be above the 1/100 year flood elevation at the discharge point. Where either or both of the above provisions are not met, we require that either a sump pump system be installed in the building or that the weepers be connected to a "third pipe". A backwater or check valve and a siphon break valve must be installed in the sump pump discharge line to prevent backflow into the basement. The "third pipe" is a relatively small diameter

pipe installed usually beside the sanitary sewer. The only connections to it are weepers. Its point of discharge to the major drainage system must be far enough downstream so that the basement floors it protects are above the 1/100 year floodwater level at the discharge point.

3. Streets and Gutters

The depth of flooding permitted on streets and at intersections during the 1/100 year storm are as follows:

a) No building shall be inundated at the ground line, unless the building has been floodproofed.

b) For all classes of roads, the depth of water over the gutter shall not exceed 0.45 metres (1.5 ft.).

c) For arterial roads, the depth of water at the crown shall not exceed 0.15 metres.

Flow across road intersections shall not be permitted for minor storms. To meet the criteria for major storm runoff, low points in roads cannot be permitted unless adequate provision is made for safe overland flow at the low points.

4. Reverse Driveways

We strongly discourage the use of reverse driveways to new houses. If their use is proposed, the proponent must ensure that a suitable degree of flood protection is provided. Reverse driveway drainage facilities may not be connected by gravity to the storm sewer system unless it can be proven that surcharging by the sewer system during a 1/100 year storm will not cause them to flood.

V. COMPUTATIONAL METHODS

Our old friend, the Rational Method, has served well. However, we need a lot more information to design proper storm water management facilities now than the Rational Method is able to give us. It has major limitations in the crude representation of physical runoff distribution in time. It can still be used for the preliminary sizing of the minor drainage system and for the final sizing only for relatively small areas up to 25 hectares. Fortunately, the computer has come to our rescue to help us get the rest of the information we need. Various hydrologic models are available which can be used depending on the type of answer or information required. We require that the design of complex drainage facilities be based on sound use of hydrologic models by experienced water resources engineers.

VI. USE OF POLICIES IN EXISTING BUILT UP AREA

As I said earlier, our new policies have only been in place for just over a year. In that time, not too much experience has been gained with their use. So far, however, it has not been too difficult to apply them in the design of the new communities. No houses have been built yet in a new community using these policies but work on one subdivision has commenced. It is going to be quite another thing, however, when it comes to using them in the existing built up area. Here we have small infilling developments, isolated projects, redevelopment in the older sections, street reconstruction, etc. Town Council in approving our new policies agreed that they should be used "to the extent possible" in the existing built up area. Therefore, we look at each development individually and see what, if anything, can realistically be done to provide storm water management. We must be very fair and realistic in this. In our own street reconstruction, we take a look at eliminating sags, if possible, or providing release points for overland flow in excess of the storm sewer design capacity. We have usually not been able to do much due to so many existing constraints. So we have also stuck with the 10 year design storm for any new storm sewers in these cases. We have required roof retention on a couple of industrial buildings due to the impervious area involved. We have specified that the average coefficient of runoff of another industrial complex not exceed 0.4. We have talked some people out of connecting rainwater leaders into storm sewers. When looking at each proposal, the first thing we ask ourselves is whether there are already any drainage problems in the area. If there are, our requirements will be different than if there aren't. Eventually, we will have Master Drainage Plans to guide us better in these areas. Until then, we will just have to do the best we can as problems and opportunities come along.

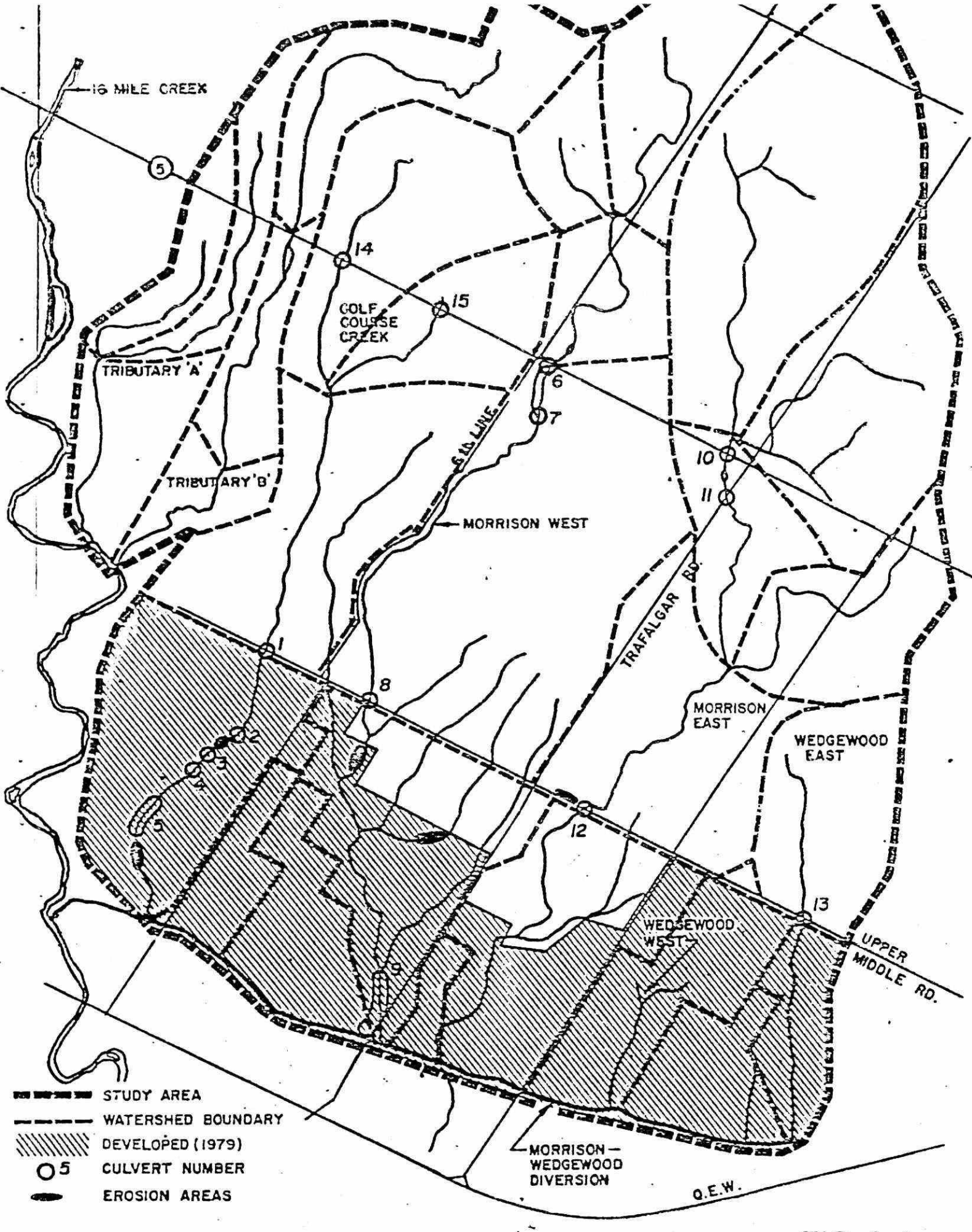
Pressure continues as before for the piping and filling of small watercourses. Most of these watercourses are on private property, often through industrial property or in people's back yards. Unfortunately, we do not have adequate legislation to prevent this from taking place on private property. Sometimes the Town has an easement available for drainage purposes. Here also the private sector does not always share our concerns for storm water management and preservation of open watercourses and is able to convince Council that they should be filled for one reason or another.

VII. SOME EXAMPLES OF OUR SWM POLICIES IN PRACTICE IN NEW COMMUNITIES

Figures A-1 to A-5 and Table A-1 are taken from the Master Drainage Plan which we completed last year. These indicate various things with regard to the Golf Course Creek which was only one of several creeks looked at in the Master Drainage Plan. Figure A-1 shows an overview of the creek, gives culvert locations and areas of existing erosion. Table A-1 summarizes data about the various culverts including their current capacities. On Figure A-2 are plots of the peaks of the hydrographs for Golf Course Creek at Upper Middle Road for various storm return periods and for pre-development conditions, post-development uncontrolled conditions, and post-development controlled conditions. You will note the overcontrol that is being exercised here because of an existing flow constraint downstream. Figure A-3, the Golf Course Creek Drainage Plan, indicates the location and extent of the flow constraint downstream of the area to be developed, and suggested locations and sizes in acre-feet of three detention areas required. On Figure A-4 are suggested storage/discharge curves for Detention Areas 1 & 3. Figure A-5 shows possible control structures for Detention Areas 1 and 2. Flood plain mapping was prepared also and delivered to the Town. Figure A-6 is taken from the Secondary Plan prepared for the River Oaks Community. It indicates some of the features we spoke of earlier - that the ravine of Golf Course Creek is to be retained as open space, there is a pedestrian trail system planned along it, there are parks planned next to it, all part of the Blue-Green Concept. Also only arterial and collector roads cross it. Figure A-7 shows the drainage areas and direction of flow in the storm sewers in the proposed subdivision. Figure A-8 shows the major drainage system for the subdivision including the extent of the detention ponds along Golf Course Creek for the 100 year storm, and the overland flow routes along the streets. You will note that the small detention pond has been changed to a park on the west side of the creek. Fig. A-9 is one of the landscaping drawings of another subdivision and it indicates the facilities to be made for public use in one of the dry ponds. Fig. A-10 shows the control structure for this same dry pond and the section through the combined roadway/dam which is to be paved with interlocking blocks to prevent washout in the event of a Regional Storm.

APPENDIX

APPENDIX



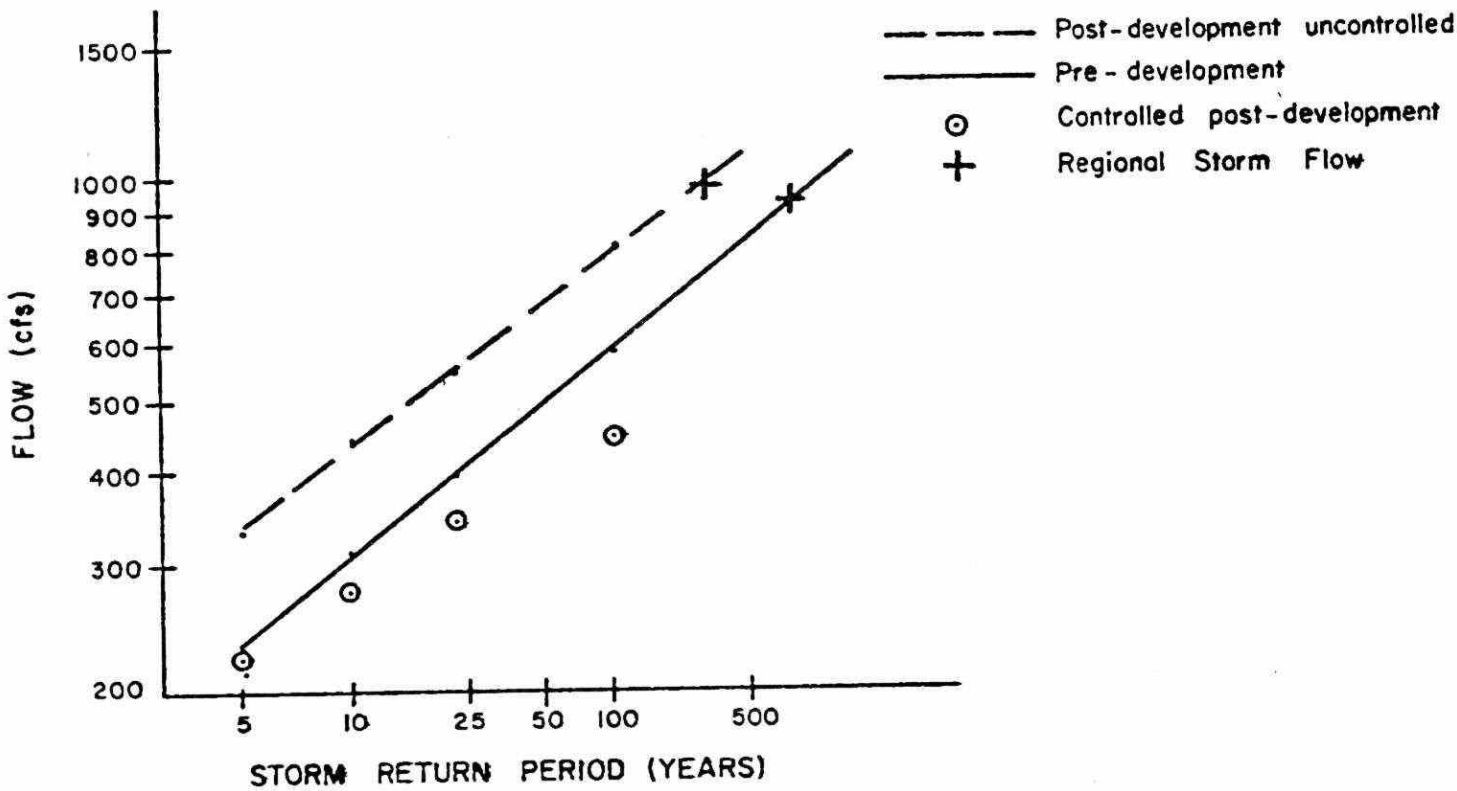
Culvert Locations & Existing Erosion Areas

FIG. A-1

TABLE 2 - FLOODPLAIN MAPPING STRUCTURE SUMMARY

STRUCTURE	TYPE AND SIZE	D/S INV	U/S INV	TOP ROAD	U/S LOW CHORD	AREA	LOW FLOW CHANNEL SIZE D/S	LOW FLOW CHANNEL SIZE U/S	STRUCTURE CAPACITY	
1. Golf Course Creek		(ft.)	(ft.)	(ft.)	(ft^2)	($ft.^2$)	(ft.)	(ft.)	cfs	Return Period
6 Culham Street	112" x 75" CSP	376.3	390.2	400.3	396.4	46	2.5 x 8	12 x 3	560	<100
4 McCraney Street	112" x 75" CSP	407.6	409.0	420.7	415.2	46	12 x 3	12 x 3	625	<100
3 Oakdale Dr. Footpath	112" x 75" CSP	412.6	413.6	425.2	419.7	46	12 x 3	12 x 3	560	<100
2 Miller Road	112" x 75" CSP	413.7	414.3	437.2	420.5	46	12 x 3	12 x 3	700	100
1 Upper Middle Rd.	112" x 75" CSP	442.4	442.8	450.8	448.5	46	14 x 2.5	10 x 2	550	100
2. Morrison West										
9 Box Culvert at Outlet	10' x 10'	365.5	381.9	421.7	391.9	100	Diversion Channel	8 x 2	2800	regional
8 Upper Middle Rd.	10' x 5'-7" Concrete Box	441.9	441.9	451.8	447.6	56	8 x 2	8 x 2	650	100
7 Farmer's Pond	13' Wide Concrete Slot Weir	543.0	550.9	552.5	-	-	8 x 2	8 x 2	-	-
6 Highway 5	10' x 6'-2" Concrete Box	549.0	549.0	562.0	555.2	62	8 x 2	-	850	regional
3. Morrison East										
12 Upper Middle Rd.	9'-5" x 14'-4" CSP	448.8	450.3	483.2	459.72	105.1	14 x 2	14 x 2	3000	regional
11 Trafalgar Road	137" x 87" CSP	538.4	539.0	552.6	546.25	69	14 x 2	14 x 2	950	100
10 Highway 5	14' x 7' Concrete Box	541.0	541.2	557.0	548.2	98	14 x 2	10 x 3	1300	100
4. Wedgewood Creek E.										
13 Upper Middle Rd.	8'-10" x 8'-2" Concrete Box	496.0	496.9	515.4	505.1	72.16	9 x 2.5	-	1225	regional
5. Additional Structures	(No mapping req'd)									
14 Highway 5, Golf Course Creek	4' x 4' Concrete Box						2 x 2	-	170	< 10
15 Highway 5, Golf Course Creek	4' x 4' Concrete Box						2 x 2	-	170	<100

TABLE A-1



GOLF COURSE CREEK
AT UPPER MIDDLE ROAD

FIG. A-2

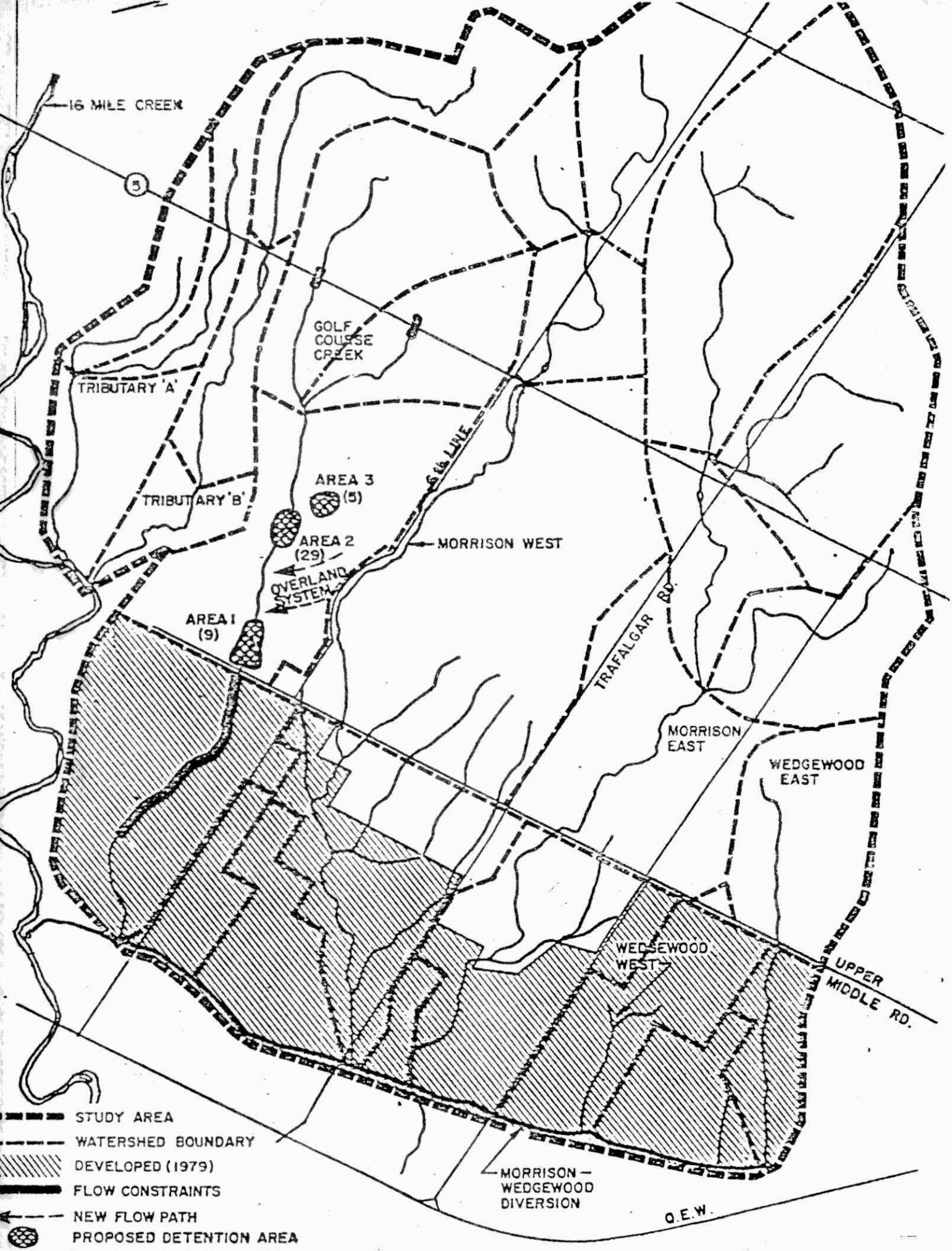
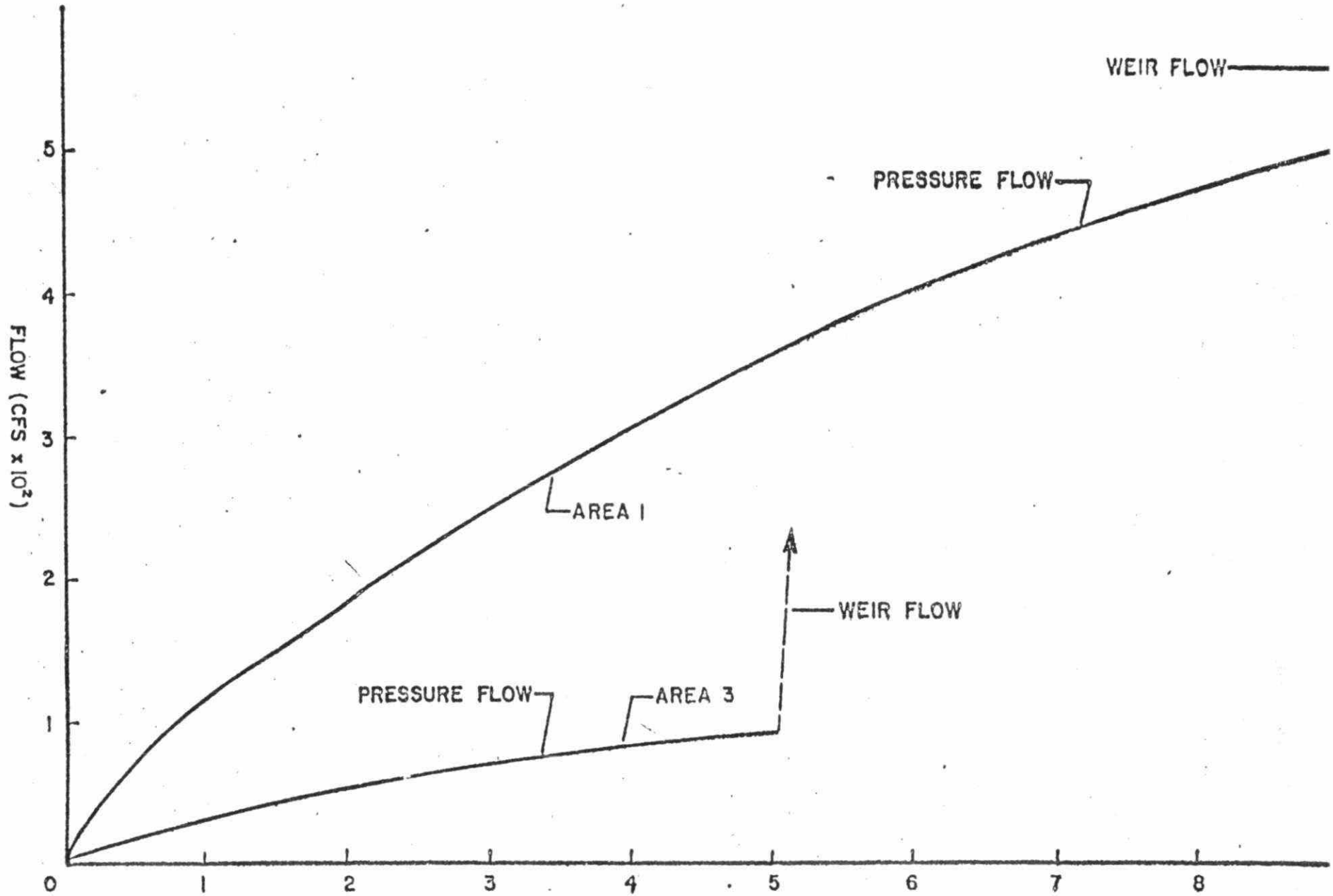


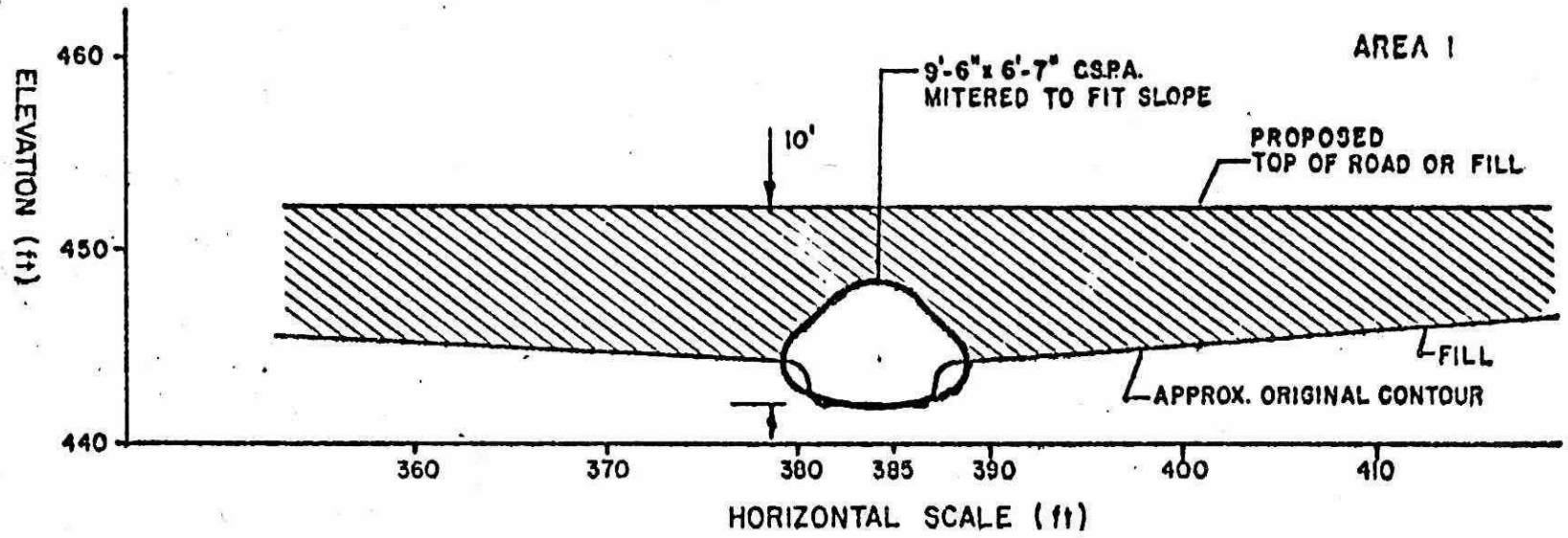
FIG. A-3

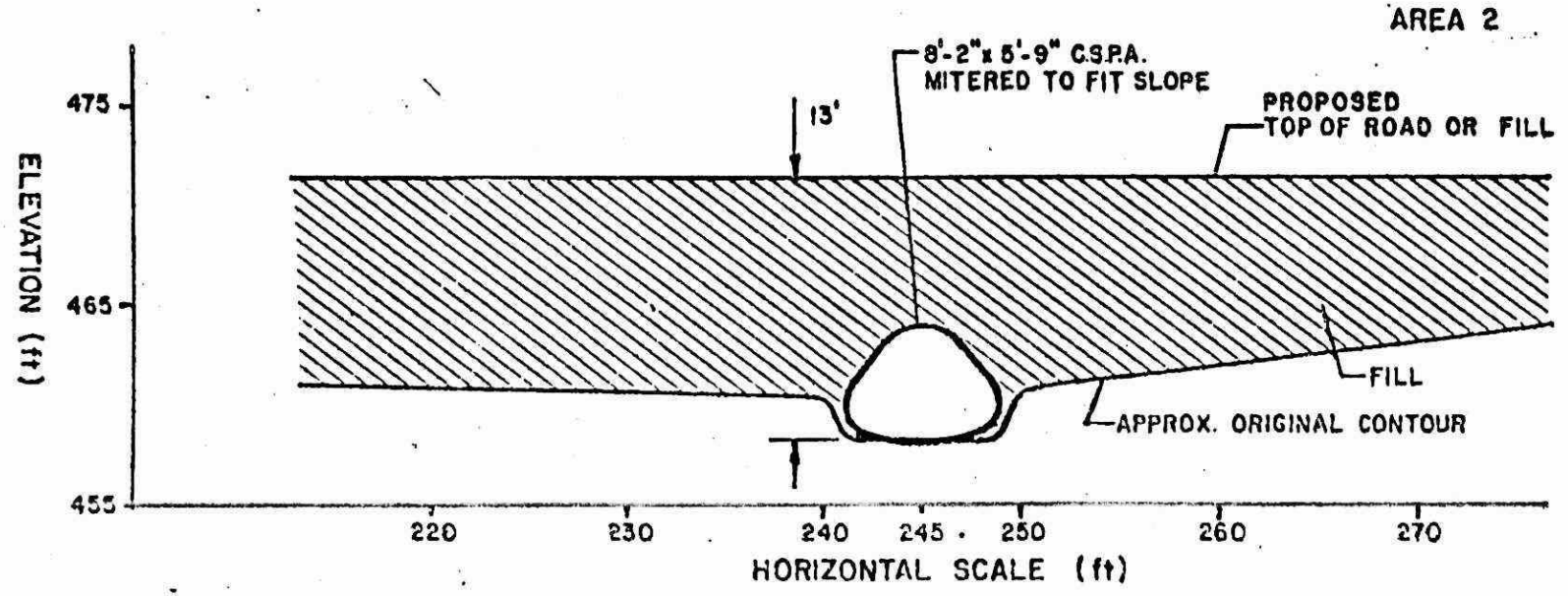
Golf Course Creek Drainage Plan



Suggested Storage / Discharge Curves for Detention Areas 1 & 3 (Golf Course Creek)

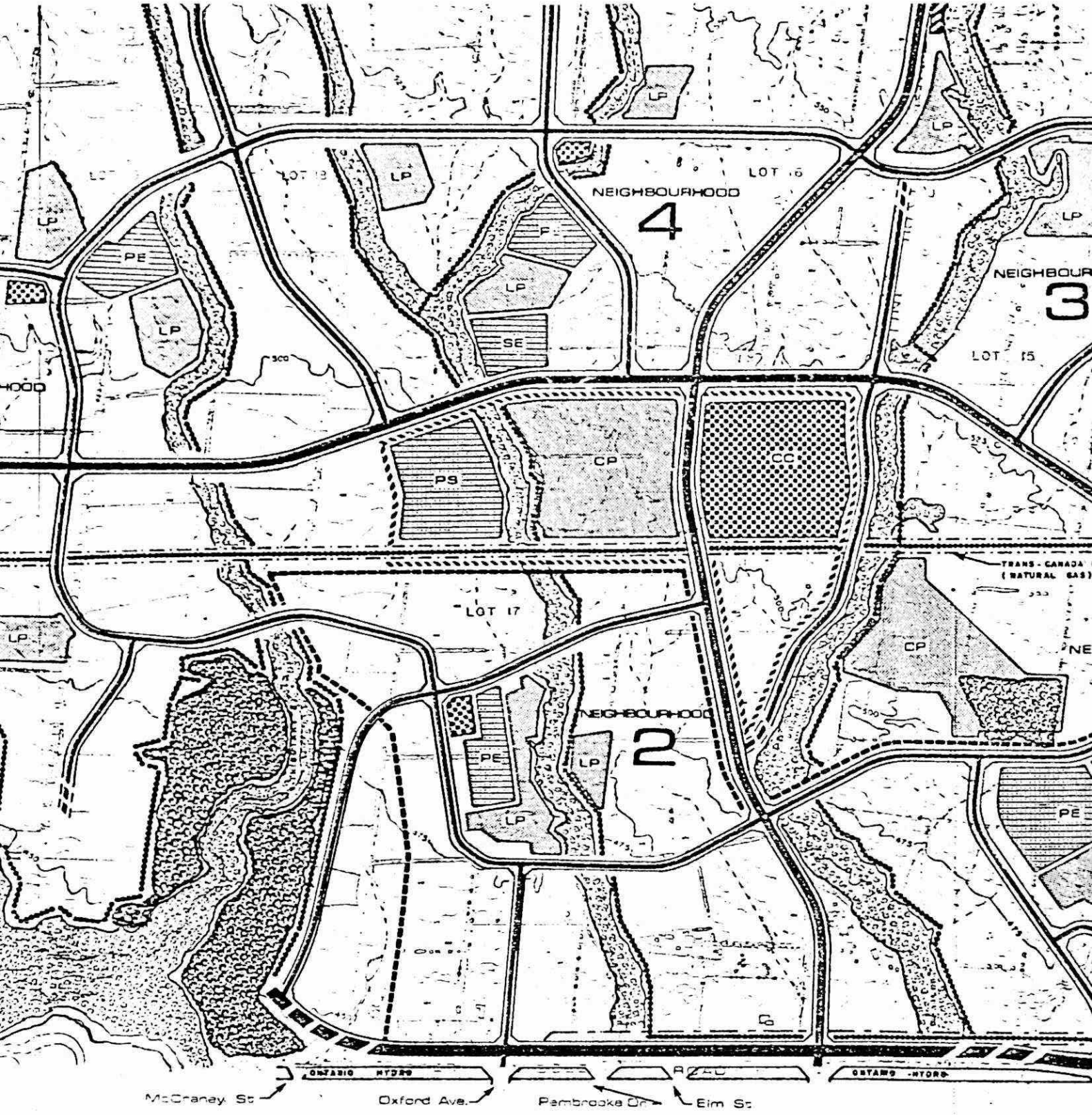
FIG. A-4





POSSIBLE CONTROL STRUCTURES
FOR DETENTION AREAS 1 AND 2

FIG. A-5



RIVER OAKS COMMUNITY SECONDARY PLAN DESIGN

FIG. A-6

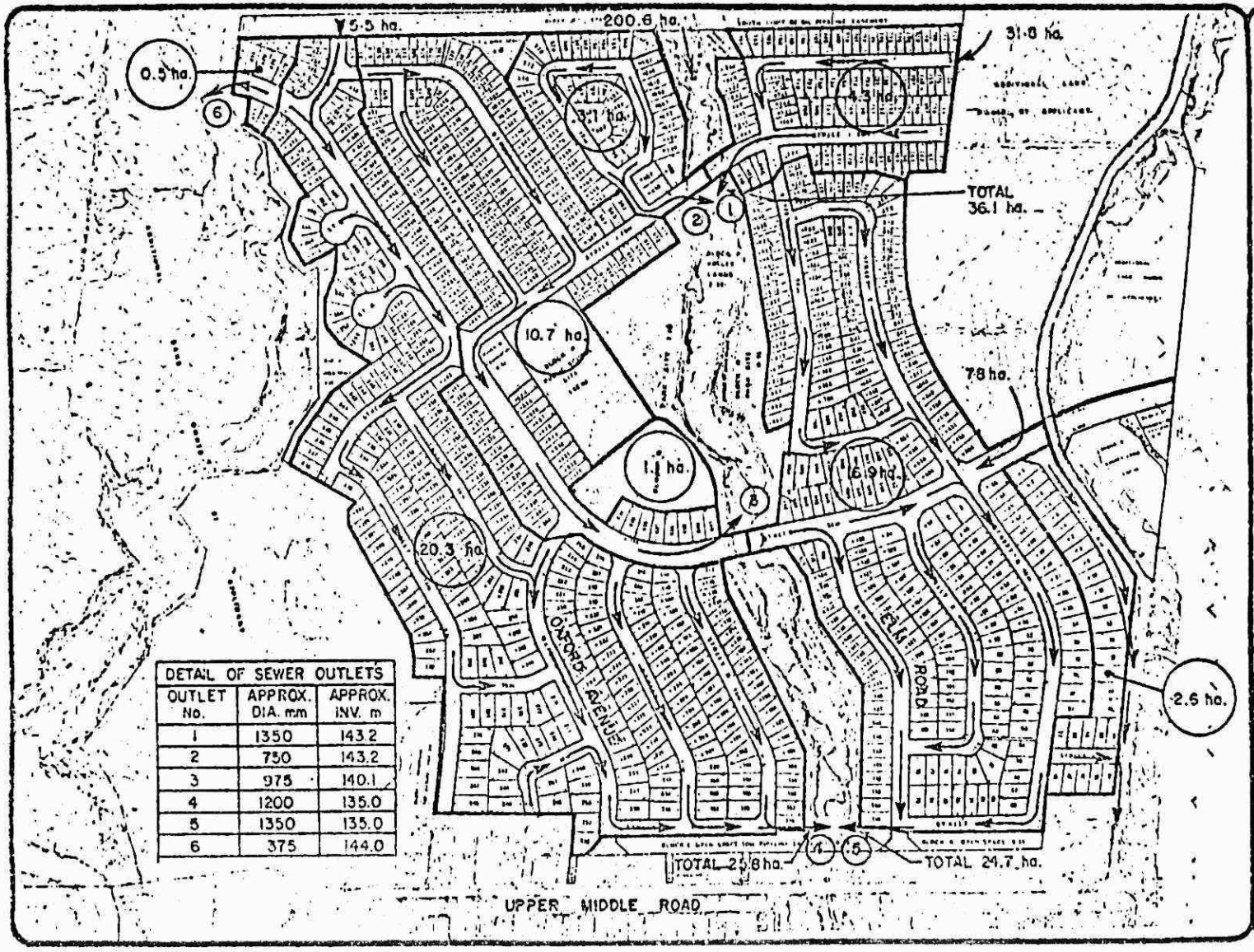

5.3 ha.
200.6 ha.
31.0 ha.
0.5 ha.
6
3.1 ha.
4.3 ha.
TOTAL
36.1 ha.
2
1
10.7 ha.
7.8 ha.
1.1 ha.
6.9 ha.
8
20.3 ha.
OXFORD AVENUE
ELM ROAD
2.6 ha.
TOTAL 23.8 ha.
4
5
TOTAL 24.7 ha.
UPPER MIDDLE ROAD
DETAIL OF SEWER OUTLETS
OUTLET No. | APPROX. DIA. mm | APPROX. INV. m
1 | 1350 | 143.2
2 | 750 | 143.2
3 | 975 | 140.1
4 | 1200 | 135.0
5 | 1350 | 135.0
6 | 375 | 144.0
Anprop Investments
Functional Report for River Oaks Subdivision Phase 1
Figure 11
Storm Sewers (Minor System Controlled) & Internal Drainage Areas
Proctor & Redfern Limited
Consulting Engineers and Planners
Toronto
E.O. 79434

FIG. A-7

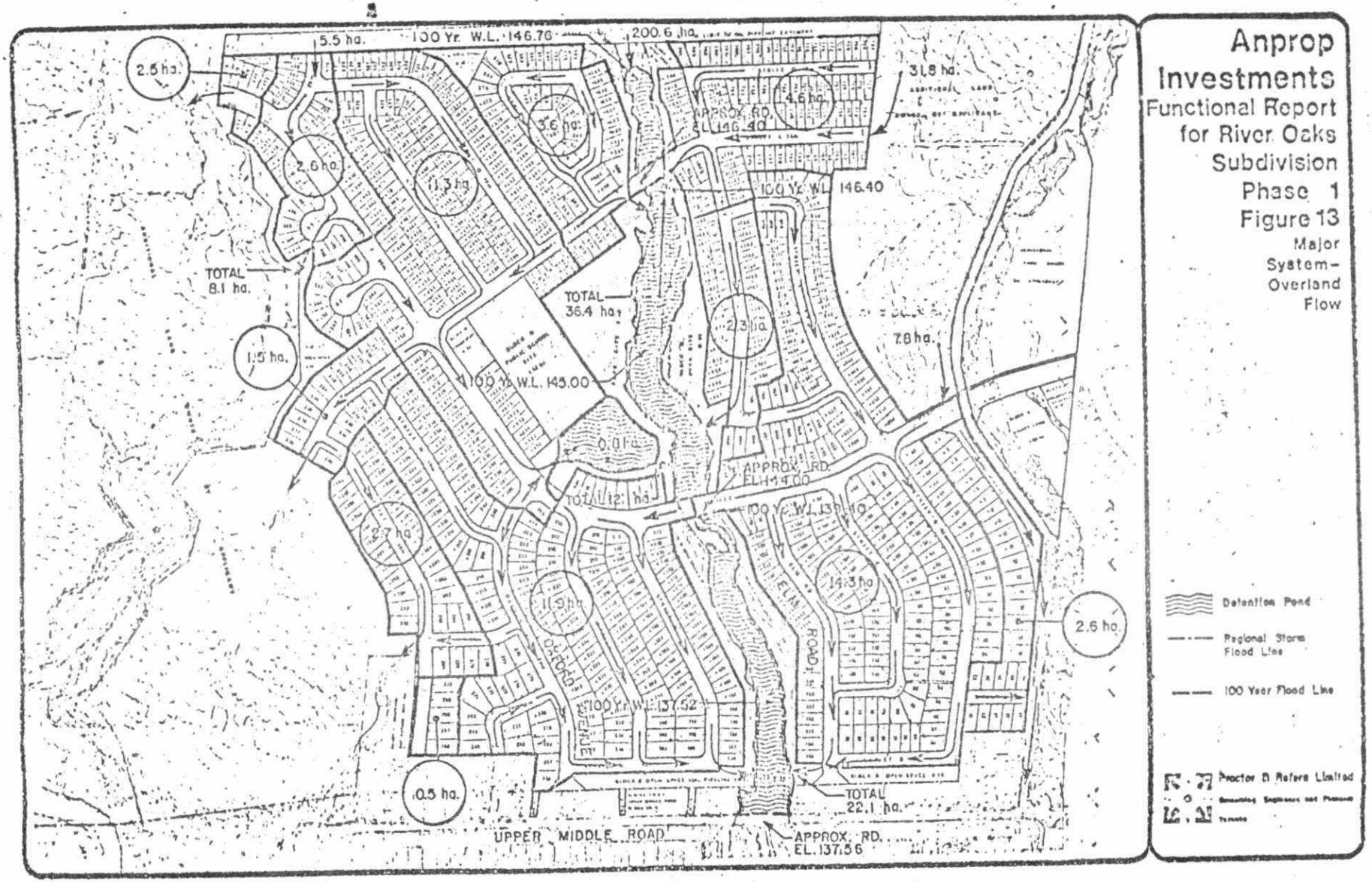

Anprop Investments
Functional Report for River Oaks Subdivision Phase 1
Figure 13
Major System–Overland Flow
Detention Pond
Regional Storm Flood Line
100 Year Flood Line
Proctor & Redfern Limited
Toronto
5.5 ha.
100 Yr. W.L. 146.76
200.6 ha.
31.8 ha.
2.5 ha.
4.6 ha.
APPROX. RD. EL 146.40
3.6 ha.
2.6 ha.
11.3 ha.
100 Yr. W.L. 146.40
TOTAL 8.1 ha.
TOTAL 36.4 ha.
2.3 ha.
7.8 ha.
1.5 ha.
100 Yr. W.L. 145.00
0.01 ha.
APPROX. RD. EL 144.00
TOTAL 12 ha.
100 Yr. W.L. 139.10
2.7 ha.
14.3 ha.
2.6 ha.
11.9 ha.
OXFORD AVENUE
100 Yr. W.L. 137.62
ELM ROAD
10.5 ha.
TOTAL 22.1 ha.
UPPER MIDDLE ROAD
APPROX. RD. EL. 137.56

FIG. A-8

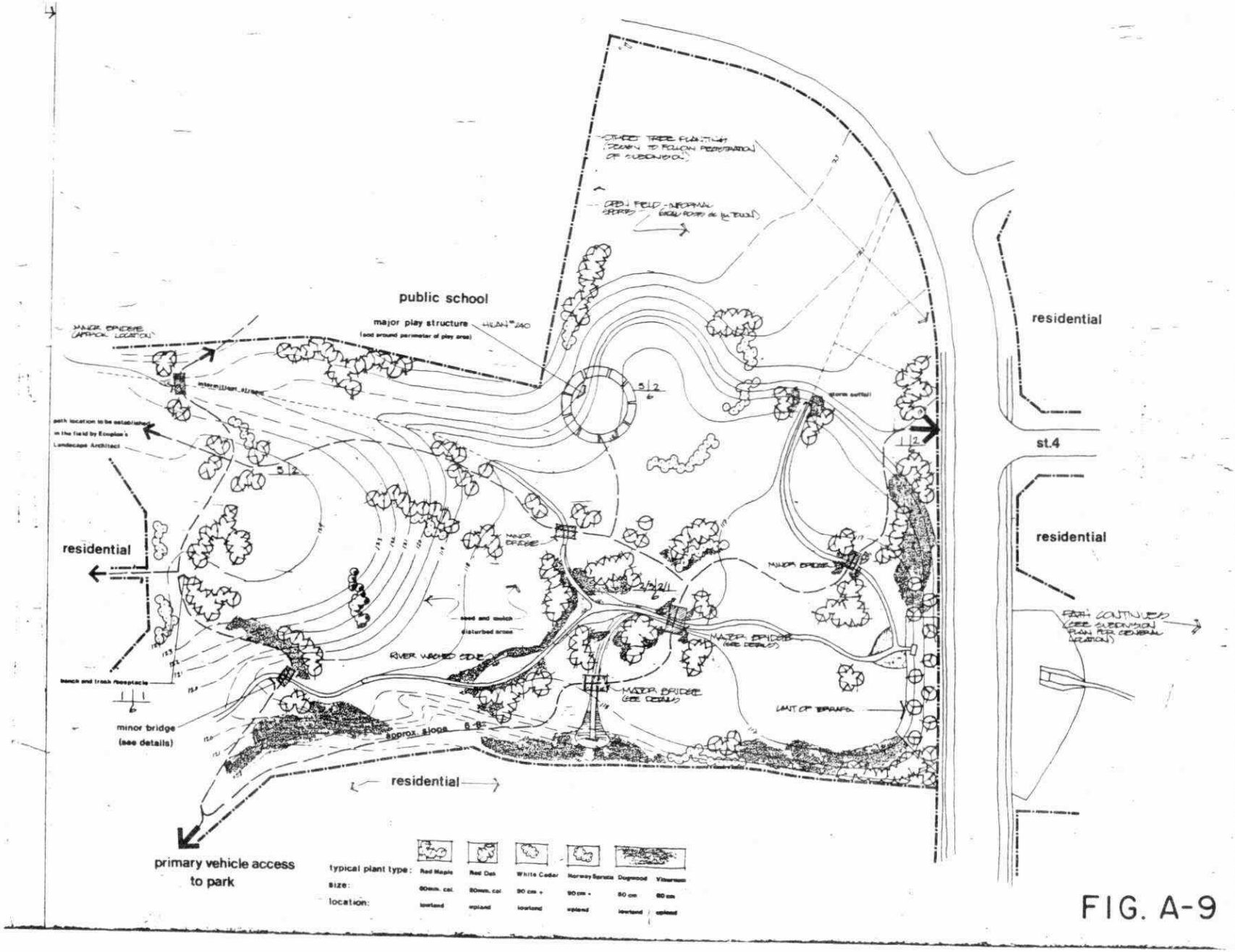


FIG. A-9

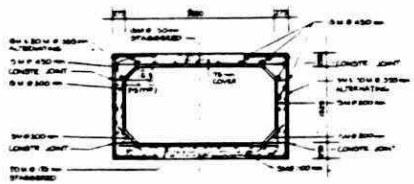
glen abbey community

genstar eastern development

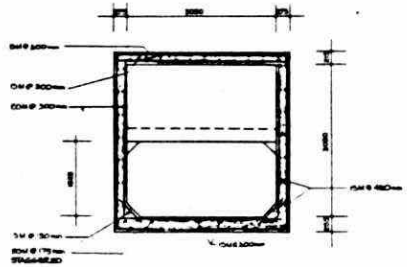
ecoplans ltd.
waterloo ont.

SITE PLAN

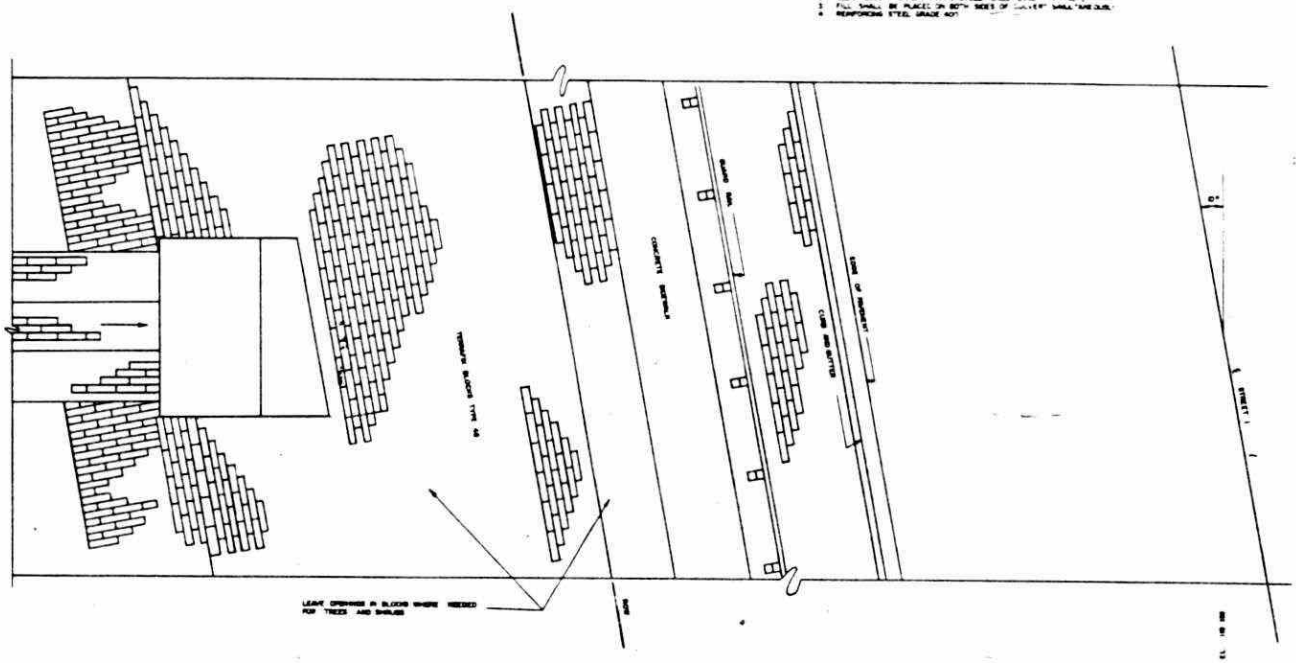
METRIC



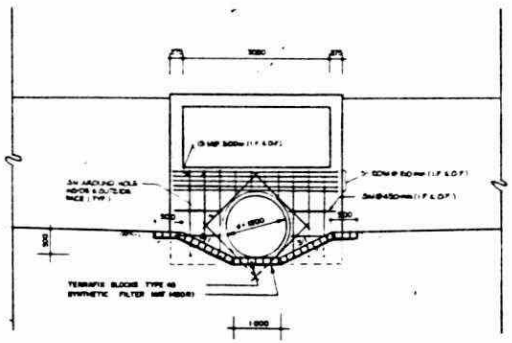
SECTION B-B



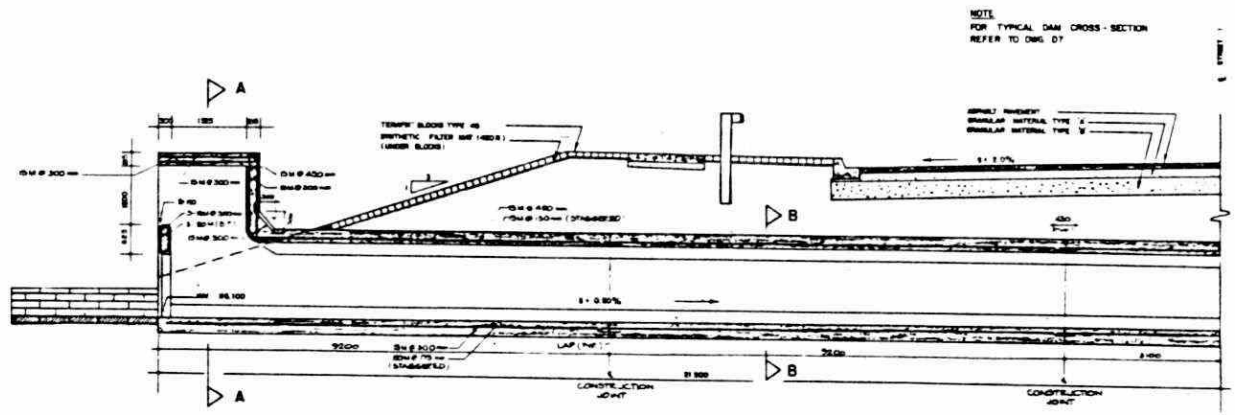
SECTION A-A



PLAN



END VIEW



CROSS SECTION

STRUCTURAL DESIGN OF CULVERTS BY UNDERWOOD McLELLAN LTD. (UMA)
HYDRAULICS DESIGN AND DAM DESIGN BY ANDREW BRODIE ASSOCIATES INC

	REVISIONS		APPROVALS		Underwood McLellan (1977) Ltd
	Date By		Municipal		Consulting Engineers & Planners
	Des'd M.B. Checked M.B.	Date NOV. 1979	APPROVED IN PRINCIPLE SUBJECT TO DETAIL CONSTRUCTION DESIGN CONFORMING TO TOWN OF OAKVILLE STANDARDS AND SPECIFICATIONS		TOWN OF OAKVILLE
	Drawn Y.B. Checked D.A.		Signed D.K. Ellis 26/6/80		THE REGIONAL MUNICIPALITY OF HALTON
	Scale 1:50		DIRECTOR OF PUBLIC WORKS		
	GENSTAR LIMITED		Regional		GLEN OAKS CREEK EAST
	GLEN ABBEY COMMUNITY		DESIGN OF SANITARY AND WATER SERVICES APPROVED SUBJECT TO DETAIL CONSTRUCTION CONFORMING TO HALTON REGION STANDARDS AND SPECIFICATIONS AND LOCATION APPROVAL FROM AREA MUNICIPALITY		DRAINAGE STRUCTURE UPSTREAM SECTION
			Signed —		FIG. A-10
			DIRECTOR OF PUBLIC WORKS HALTON REGION		

PRACTICAL IMPLEMENTATION OF STORM WATER MANAGEMENT TECHNIQUES - IS IT A REALITY, A DAY-DREAM OR A NIGHTMARE?

BY

F.I. LORANT, P.ENG.

Chief Water Resources Engineer

Paper presented at the seminar on
Practical Implementation of
Storm Water Management, Toronto.
October 1980

PRACTICAL IMPLEMENTATION OF STORM WATER MANAGEMENT TECHNIQUES - IS IT A REALITY, A DAY-DREAM OR A NIGHTMARE?

BY

F.I. LORANT, P.ENG.

Chief Water Resources Engineer

M.M. Dillon Limited

ABSTRACT

The success in practical implementation of storm water management has not matched the recent advancements in planning, analysis and control of urban drainage.

Planning of storm water management must begin by preparing a Master Drainage Plan for all watersheds within the Municipality, backed by clearly enunciated policies and supported by the development industry and the public. Analysis of the rainfall-runoff process by computers is widespread but a careful selection of the most appropriate model is recommended. Control of runoff is a key element in storm water management, however, limiting runoff for the sake of control could result in unnecessary expenditures.

Mr. Chairman, thank you for inviting me to address this group on a topic which I feel is perhaps the most neglected component of storm water management, namely practical implementation. In my opinion this seminar should have been organized some ten years ago when we still believed that the Rational Formula is rational, when detention was only practiced by the police, when SWMM was a sport and "zero increase" referred only to the money included in our January pay-slip.

Paper presented at the seminar on Practical Implementation of Storm Water Management, Toronto. October 1980.

The original topic of my talk was on the development of municipal drainage policies with special emphasis on the Kitchener Urban Drainage Policy document[1] prepared in 1979. However, in view of an earlier presentation this afternoon on the Oakville Urban Drainage Policy, a document which in many respects resembles very closely the Kitchner policies, I decided to use this opportunity to talk in general terms about storm water management, with occasional references to the Kitchener case.

I fully realize that many of you are familiar with the topic, for those I will try to make it all sound new. For those who find storm water management new, I will try to make it sound familiar and for those who suffer from insomnia, I will show some slides.

No matter which side of the fence you find yourself, the old traditional methods of dealing with urban drainage began to create increasing problems in the early 1970's. The limitations of these older drainage practices are summarized on Figure 1.

A new approach evolved over the past decade a technique which is commonly referred to as Storm Water Management. Storm Water Management is the planning, analysis and control of urban drainage in order to minimize health hazards and property damages. Let us consider the practical implementation of these three aspects of Storm Water Management.

PLANNING

Ideally, planning should begin with the preparation of a Master Drainage Plan for the whole community. Since the preparation of such a Plan can take several years, in most cases early application of storm water management proceeds without the existance of such a Master Drainage Plan. The major activities involved in the

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1. *M.M. Dillon Limited, Urban Drainage Policy, City of Kitchener, May 1979.*

preparation of a Master Drainage Plan is shown on Figure 2. The implementation of storm water management techniques without the existance of a Master Drainage Plan should be based on interim policies. These policies can be subsequently revised, if necessary, after the completion of the Master Drainage Plans, a method described in more detail further in this paper.

The first step in the preparation of a Master Drainage Plan is the definition of Objectives. Figure 3 shows the Kitchener storm drainage policy objectives. These objectives are followed by design criteria policies, which reflect the stated objectives, and should be general in nature. Figure 4 lists the Kitchener urban drainage policies.

ANALYSIS

The earliest method of analysis used for predicting peak flows, known as the Rational Method, worked well for over 80 years. With experience, engineers developed the knack for selecting runoff coefficients which provided results they could live with. The diversity of runoff coefficients used across Canada is bewildering as shown on Figure 5. Frankly, I am not surprised with the result. If Canadians cannot agree on a simple issue such as the patriation of the Constitution, how can you expect them to agree on the selection of runoff coefficients?

The introduction of hydrograph methods represented an improvement over the Rational Method, but the results were not always encouraging.

Computer simulation of the rainfall-runoff process became fashionable in the early 1970's. In the beginning, every university and research group became convinced that it is their turn to bring out better, more sophisticated computer program to analyse urban drainage.

With these new programs we produced a new generation of engineers who were raised on the computer. Some of these young engineers actually believe the numbers that come out initially from the computer. Some others merrily go along and design a small 10 inch diameter sewer with a monstrous program which may cost several hundred dollars to run. I suppose they believe that "what separates the men from the boys is the price he pays for his toys".

Undoubtedly the computer age meant a great advancement in the field of storm water management, but we have to learn how to be more selective. Almost all the programs currently used require the input of a wide range of factors. If such data is not available and we have to guess all the input parameters, why not guess the answers as well?

During the past 5 years considerable effort is being concentrated on setting up data gathering stations to measure rainfall, runoff quantity and quality, temperature and other parameters necessary to calibrate the computer models. With calibration and subsequent verification we can achieve remarkable results in simulating urban runoff. Figure 6 shows an example of a data gathering system, recording synchronized rainfall, flow water quality and temperature.[1] Unfortunately, at present, the results of water quality modelling are discouraging.

I am convinced in the long run, computers will be able to predict with great accuracy, the quantity and quality of urban runoff. Eventually computers will achieve a level of sophistacation which will create a situation where some of us will not be able to use our professional judgement. Perhaps just as well.

Practical implementation of storm water management techniques requires some curtailment of acceptable computer programs used in submissions to approval agencies. On the one hand, the selection of a single

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1. *M.M. Dillon Limited, Storm Water Management Model Verification Study, Canada-Ontario Agreement on Great Lakes Water Quality Research Report No. 97, 1979.*

program may be inappropriate as it restricts the designer and hinders progress. On the other hand, the free selection of computer programs would make the approval process a nightmare. In Kitchener, the designer was given a choice of three methodologies: Rational method for a single pipe, SWMM or Illudas programs for more complex systems.

The analysis of the rainfall-runoff process requires the selection of various design criteria. Design storms used in drainage projects range from a low rainfall event such as a 2-year storm to the infinitely large storm called Probable Maximum Storm, as shown on Figure 7.

The Kitchener Policy requires the designer, under the Major-Minor concept, to use the following criteria:

i) The Major system must provide protection against flooding, equivalent to that provided by the flood plain criteria recommended by the Ministry of Natural Resources and endorsed by the Grand River Conservation Authority.

ii) Minor systems should be designed for the level of convenience appropriate for the area being drained. Excessive costs due to over-design can be avoided as the Major system will provide protection against storms which exceed the capacity of the Minor system.

The design storm frequency to be adopted for the planning and design of minor storm drainage facilities, shall be decided for each individual case, so that an optimum balance between protection and cost can be obtained.

In the absence of an economic evaluation, a design storm frequency of 1 in 5 years shall generally be adopted for all land uses.

For commercial areas, a design storm frequency of 1 in 10 years shall be considered to further reduce the inconvenience. Surcharge in the downstream areas due to the higher runoff from the commercial area must be avoided. This can be achieved by providing storage facilities.

Proposals for redevelopment in flood plain areas will be assessed on an individual basis.

CONTROL

Control of urban runoff is the most complex and misunderstood part of storm water management. Any change in land use will affect the runoff. Urbanization results in increased peak flows; if left uncontrolled, this increase can create flooding and erosion problems downstream. The most commonly used control methods are listed in Figure 8.

The extent of control should be dictated by downstream constraints. Control of runoff could not be equally affective for all sizes of floods for technical reasons, therefore, the selection of control flood is an important engineering and economic exercise.

To indicate the effect of detention on peak runoff, flows generated in a 60 acre subdivision have been computed and presented in Figure 9. Development of the subdivision results in a marked increase in peak flows. Selecting a five year predevelopment flow for control, the effect of the pond is diminished as the runoff is increased. For example, in the case of the 100-year post-development flow, the effect of a detention pond designed to control a 5-year flow is negligible.

Control can also be beneficial in improving the water quality of urban runoff during and after construction. Figure 10 illustrates the recent results obtained from data collected in Winnipeg detention ponds.

The introduction of storage ponds can raise a number of questions which have to be considered at an early stage of planning. Figure 11 lists the legal, environmental, safety, political and maintenance problems related to storage encountered in the past.

In many instances, when applying control of storm water the tendancy is to neglect defining the objectives. This could result in a set of overly specific and rigid criteria for designing the storm water management system. These rules are applied, often regardless of the suitability and the needs of a particular area.

In Kitchener, the policies require that the peak runoff rates from areas of new development shall be controlled where downstream constraints are evident. These constraints will be determined in the Master Drainage Plan. Until the completion of such a plan, post-development flows from a 100-year return frequency storm shall not exceed the predevelopment runoff for the same storm in the major system.

In undeveloped watersheds the increase in runoff due to future development would not cause flooding constraints downstream. However, any future development must conform to the flood line criteria outlined in the policy. The control of more frequently occuring floods, such as the 2 or 5-year floods, which cause most of the erosion damage should be considered. Consequently, in undeveloped watersheds, until the completion of the Master Drainage Plan, post-development flows from the 5-year return frequency storm, shall not exceed predevelopment runoff for the same storm in the major system. Outlet control at the storage facility to achieve this condition should ensure that the post-development flows from less frequent storms, between 5 and 25-year frequency events are also reduced.

Where downstream constraints exist in the minor system, until the completion of the Master Drainage Plan, post-development runoff

from a 5-year return frequency storm shall not exceed the flows for predevelopment conditions for the same storm.

APPROVAL PROCESS

Perhaps the main reason why implementation of storm water management is lagging behind the theoretical advancements made during this decade is the complex approval process which involves numerous provincial, regional, and local government as well as Conservation Authority staff. Figure 12 shows a schematic diagram of this complex set up.

I hope the Urban Drainage Implementation Committee to be formed in the near future will consider the alternative of simplifying the existing approval process.

The major component in the development approval process in Ontario comes from municipal governments. The constant changes by these governments result in more sophisticated designs, higher servicing standards which require an ever increasing time for approvals and, according to developers, in an ever increasing housing costs. These changes come about due to the effort by the municipalities to keep up with technical innovations, to follow provincial guidelines or to react to public pressure. Each new set of criteria or standards may seem logical in isolation, but the cumulative effect of the old and new standards make many consultants confused and many developers worried.

Experience has shown that where the local municipality and the provincial approving agency had a clearly enunciated program with the necessary political commitment, storm water management had the backing of both the development industry and the public.

However, administrators, especially at the municipal level, must recognize and understand that the new storm water management policies will affect not only the engineering, but planning, parks and recreation, and legal department operations. Politicians must

also be involved at the early stages. How can we expect political lay persons to make responsible decisions without adequately explaining to them the reason for this significant new approach in urban drainage?

Developers must recognize that urbanization affects the quantity and quality of runoff. In most cases, some type of control of runoff is necessary in order to avoid flooding, erosion and deterioration of water quality at the downstream communities. The cost of design and construction of urban drainage using storm water management techniques may be higher than the old conventional methods, but only in the short-term. The long-term benefits derived by the local environment will outweigh the short-term costs.

In parting, I would like to emphasize that urban drainage, just as everything else in our modern life, is extremely complex. So, instead of the audacity of some of the experts who guarantee instant solutions by the new emerging technology in the field of urban drainage, I am more inclined towards humility by recognizing the challenge we engineers have to face. I sincerely hope practical implementation of storm water management will not permit what in the past was called "An Act of God" to turn out to be "An Act of Criminal Negligence".

Thank you.

FIGURE 1

LIMITATIONS OF CONVENTIONAL DRAINAGE PRACTICES

1. Rapidly escalating expenditures.
2. Too many agencies involved, unnecessary delays.
3. Flooding overland or through surcharged connection due to storms greater than the sewer design storm.
4. Pollutants from the urban area are washed into the receiving stream.
5. Increased runoff from new development.
6. Depletion of ground water.
7. Inadequate design tools (rational method).
8. Loss of recreational and aesthetic potential along some watercourses.

FIGURE 2

MAIN ACTIVITIES OF A MASTER DRAINAGE PLAN

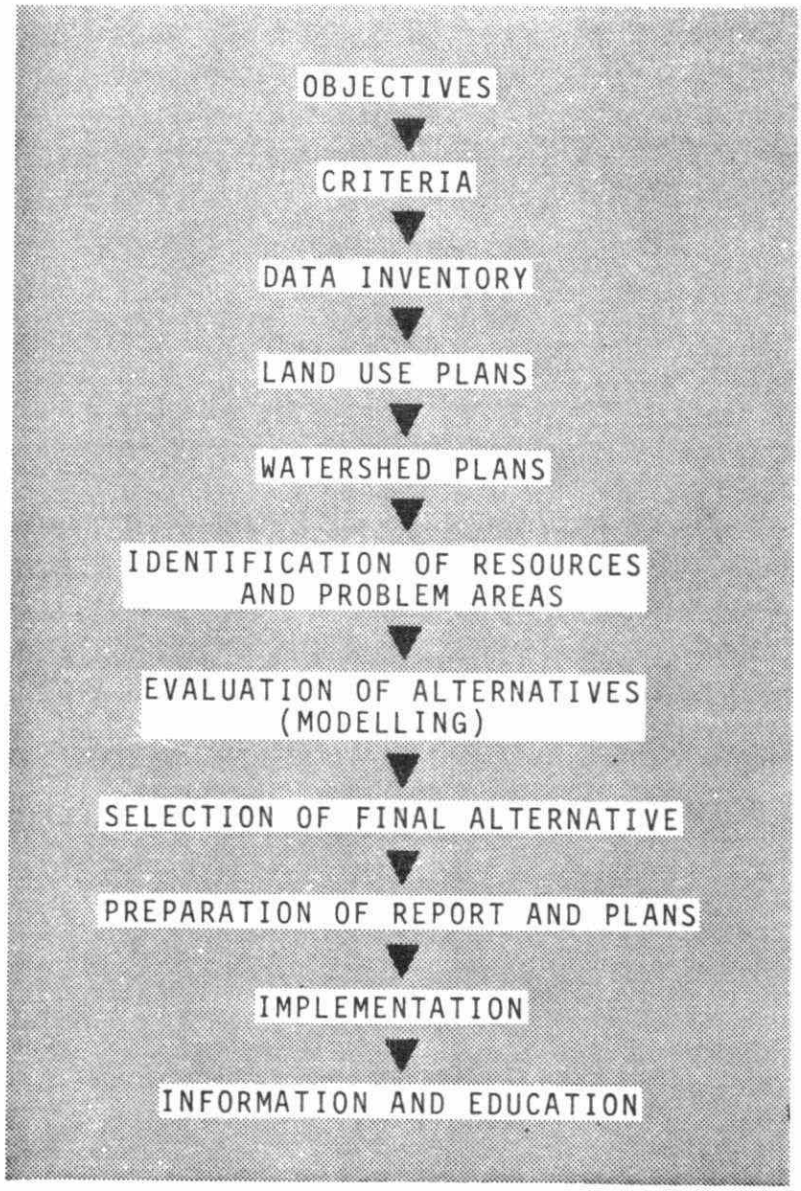


FIGURE 3

STORM DRAINAGE POLICY OBJECTIVES - CITY OF KITCHENER

1. PREVENT LOSS OF LIFE AND MINIMIZE PROPERTY DAMAGE.
2. ELIMINATE OR REDUCE TO THE MINIMUM, SURFACE PONDING AND FLOODING CAUSING INCONVENIENCE.
3. MINIMIZE THE EFFECT OF DEVELOPMENT ON RECEIVING WATERCOURSES AND ON LOCAL GROUND WATER.
4. AVOID FLOODING AND EROSION DOWNSTREAM OF THE DEVELOPMENT.
5. MINIMIZE POLLUTION OF WATERCOURSES DUE TO DEVELOPMENTS.
6. ELIMINATE ADVERSE EFFECTS OF CONSTRUCTION ACTIVITIES ON RECEIVING WATERCOURSES.
7. MINIMIZE THE TOTAL COST OF THE DRAINAGE SYSTEM AND RELATED WORKS BY USING THE LATEST PROVEN DESIGN AND CONSTRUCTION TECHNIQUES.

FIGURE 4

STORM DRAINAGE POLICIES FOR THE CITY OF KITCHENER

1. Storm drainage systems shall be designed using the major-minor concept.

2. New subdivisions shall consider the effects of the proposed development on the existing drainage regime and if necessary, carry out mitigative measures, as required.

3. Subdivision proposals shall include erosion and sediment control measures.

4. The municipality shall develop a Master Drainage Plan for the City of Kitchener.

FIGURE 5

RANGE OF RATIONAL METHOD RUNOFF COEFFICIENTS USED ACROSS CANADA

Coefficient of Runoff (C)	C	No.	% of Total
Residential	0.2 - 0.29	1	2.8
	0.3 - 0.39	12	33.3
	0.4 - 0.49	16	44.4
	0.5 - 0.59	5	13.9
	0.6 and over	2	5.6
		36	100.0
Commercial	0.5 - 0.59	1	2.9
	0.6 - 0.69	8	22.9
	0.7 - 0.79	9	25.6
	0.8 - 0.89	2	5.7
	0.9 and over	15	42.9
		35	100.0
Industrial	0.3 - 0.39	2	6.7
	0.4 - 0.49	2	6.7
	0.5 - 0.59	4	13.3
	0.6 - 0.69	7	23.2
	0.7 - 0.79	11	36.7
	0.8 - 0.89	2	6.7
	0.9 - 0.99	2	6.7
		30	100.0

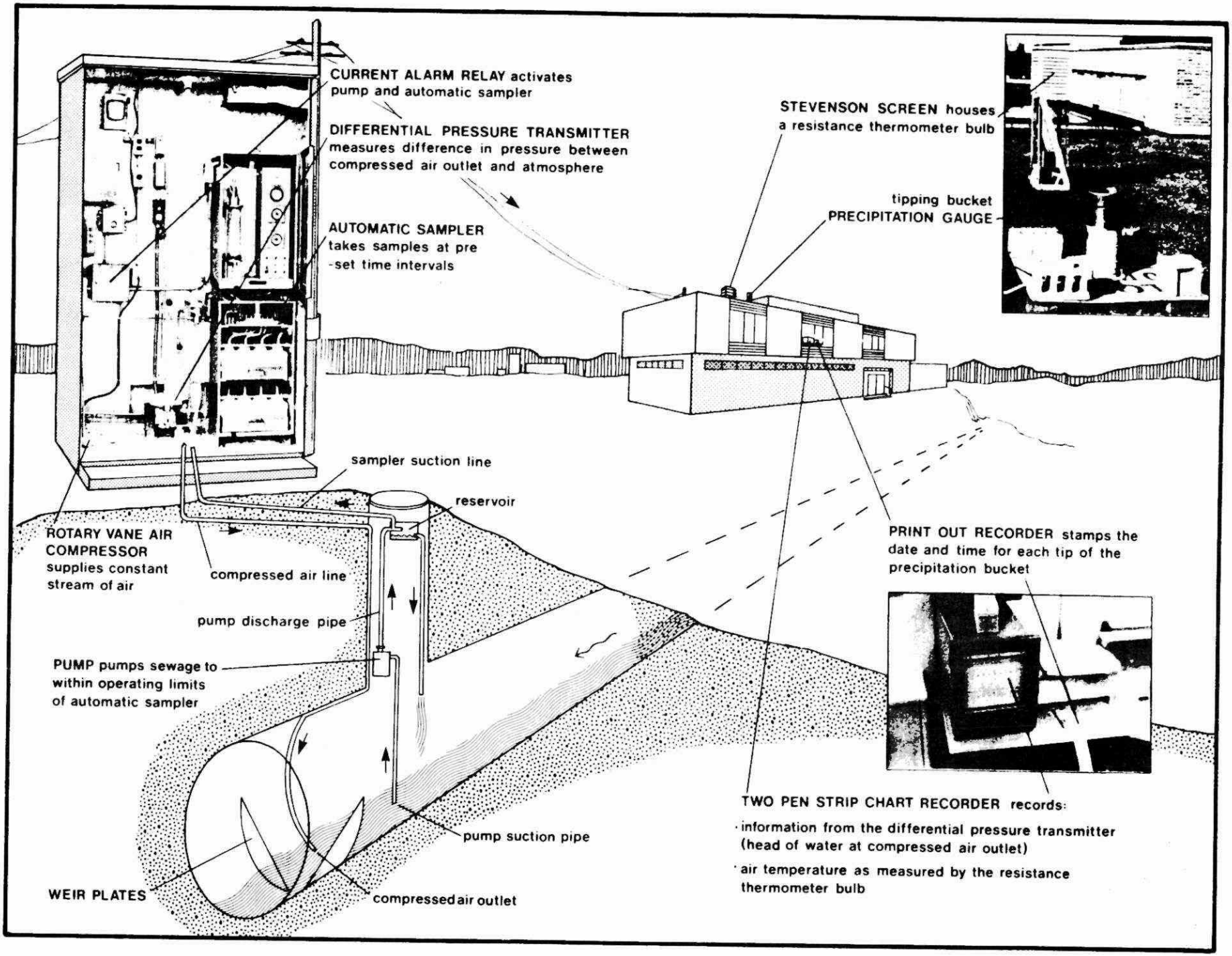

CURRENT ALARM RELAY activates pump and automatic sampler
DIFFERENTIAL PRESSURE TRANSMITTER measures difference in pressure between compressed air outlet and atmosphere
AUTOMATIC SAMPLER takes samples at pre -set time intervals
STEVENSON SCREEN houses a resistance thermometer bulb
tipping bucket PRECIPITATION GAUGE
sampler suction line
reservoir
ROTARY VANE AIR COMPRESSOR supplies constant stream of air
compressed air line
pump discharge pipe
PUMP pumps sewage to within operating limits of automatic sampler
PRINT OUT RECORDER stamps the date and time for each tip of the precipitation bucket
TWO PEN STRIP CHART RECORDER records:
· information from the differential pressure transmitter (head of water at compressed air outlet)
· air temperature as measured by the resistance thermometer bulb
pump suction pipe
WEIR PLATES
compressed air outlet

FIGURE 6

SCHEMATIC OF DATA ACQUISITION SYSTEM

FIGURE 7

DESIGN CRITERIA FOR FLOOD COMPUTATIONS

TYPE OF PROJECT	DESCRIPTION	DESIGN CRITERION
Flood Plain Regulations	Most Provinces	100 yr. flood
	Northern Ontario	Timmins Storm
	Southern Ontario	Hurricane Hazel
Dams	Possible loss of life	Probable maximum flood
	No loss of life	Regional Storm
Highway Bridge or Culvert Opening	Major Freeway	100 yr. flood
	Urban 2 lanes	50 yr. flood
	Secondary Highways	25-50 yr. flood
	Township Roads	25 yr. flood
Storm Drainage	Open watercourses in heavily built up areas	100 yr. flood
	Retention or detention ponds	5-100 yr. flood
	Storm drainage in closed conduits	2-10 yr. flood
	Airport	2-10 yr. flood
Agricultural Drainage	Terraces and diversion channels	10 yr. flood
	Waterways	10 yr. flood
	Structures	25 yr. flood
Ponds	Storage	2-5 yr. flood
	Spillway	25-100 yr. flood

FIGURE 8

RUNOFF CONTROL MEASURES

1. On-site storage on roof and parking lot.
2. Temporary detention ponds (dry ponds).
3. Retention ponds (wet ponds).
4. Reduced imperviousness (disconnection of roof leaders).
5. Slower conveyance facilities (grassed swales).
6. Increased infiltration i.e. porous pavement or recharge ponds.

FIGURE 9

RESULT OF FLOOD CONTROL IN A 24.3 HECTARE (60 Acre) SUBDIVISION

DRAINAGE AREA CONDITION	RETURN PERIOD OF STORM-YEARS 5	10	25	50	100
1. Existing-undeveloped	9	15	24	32	41
	.25	*.42*	*.68*	*.91*	*1.16*
2. Developed without control	33	66	79	99	111
	.93	*1.87*	*2.23*	*2.80*	*3.14*
3. Developed with 1 in 5-year control	9	31	70	93	110
	.25	*.88*	*1.98*	*2.63*	*3.11*

NOTE: Estimated peak flows in cfs.
Estimated peak flows in cubic metre per second

FIGURE 10

RETENTION POND STORM WATER QUALITY IN mg/l
(Data observed in Winnipeg)

Parameter	POND 1			POND 2		
	Inflow	Outflow	% Reduction	Inflow	Outflow	% Reduction
Suspended Sediment	308.2	19.0	94	1182.8	87.1	93
Total Organic Carbon	25.6	11.9	54	63.9	14.3	78
5 day Bio-chemical Oxygen Demand	7.5	4.7	37	8.7	7.3	16
Total Kjeldahl Nitrogen	3.4	1.7	50	5.4	3.7	31
Nitrate (NO_3)	0.4	0.04	90	4.7	1.4	69
Total Phosphorous	0.6	0.2	67	1.3	0.4	69
Lead	0.4	0.04	90	1.0	0.1	90
Chloride	10.6	18.3	-73	32.3	300.4	-830

FIGURE 11

PROBLEMS RELATED TO STORAGE

Legal

- Can developers be required to use part of their land for storage?
- If reimbursed, should market values be used for land values?
- Can developers be expected to pay part or total cost of storage facilities?
- Can developers be required to store runoff from outside areas?
- Can developers be forced to maintain storage facilities?
- Who is liable for future upgrading?
- In case of flood damage, who is liable?

Environmental

- Algae, Weed
- Mosquitoes
- Pollution
- Debris
- Sediment

Safety

- Fencing or no fencing, attractive nuisance

Political

- Design criteria for sewers, storage facilities and outlet structure. Too many agencies involved.

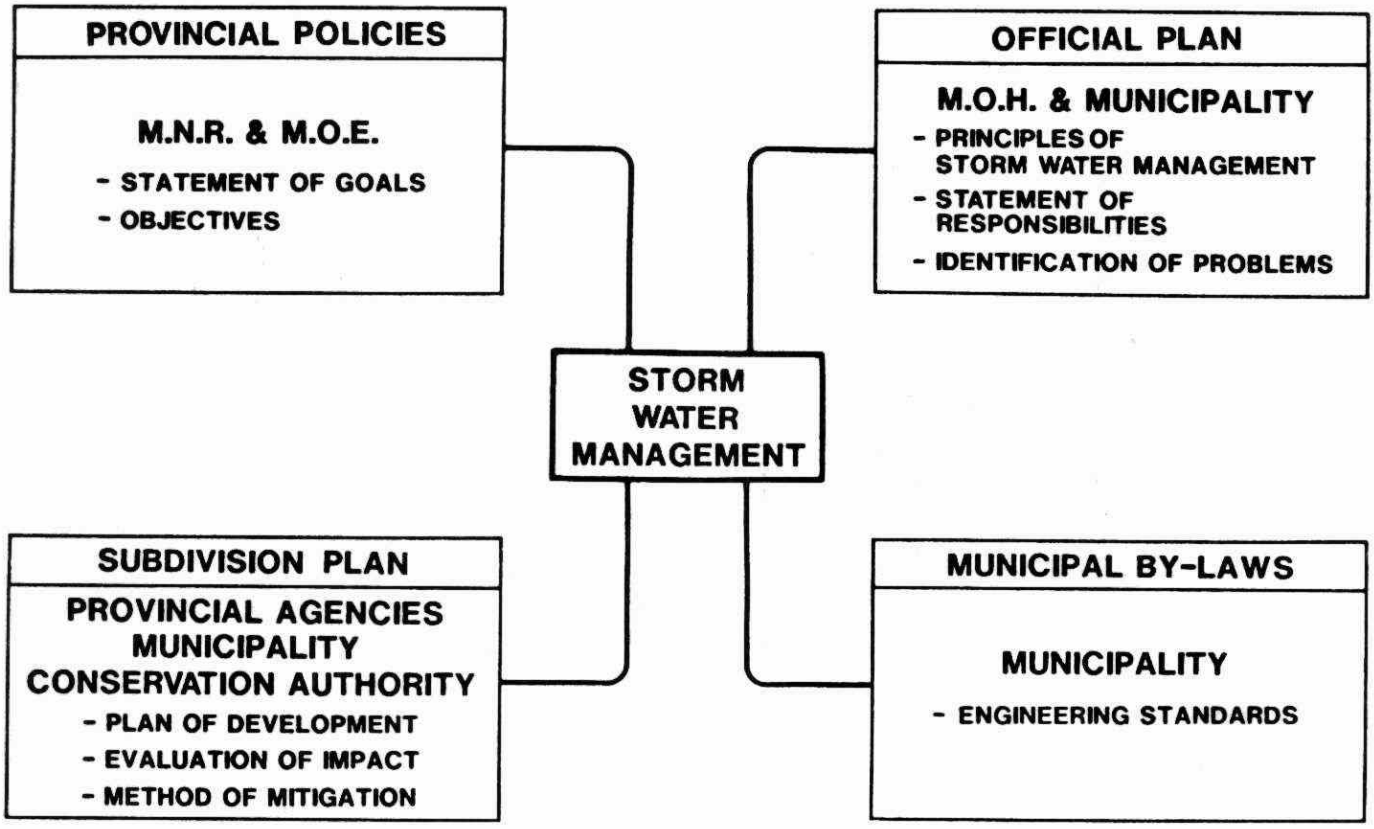
Maintenance

- Storage Ponds - Public responsibility?
- Roof Top - Landowners responsibility?
- Car Park - Land owners responsibility?

Public acceptance ?

FIGURE 12

AGENCIES DEALING WITH STORM WATER MANAGEMENT



DEVELOPMENT OF MUNICIPAL DRAINAGE POLICIES IN THE TOWN OF MARKHAM

By: Brian Wigglesworth

Presentation To The Seminar
On Practical Implementation Of
Storm Water Management Technique

STORM WATER MANAGEMENT

In 1977 The Council of the Town of Markham adopted a policy whereby all future subdivisions are to be designed using storm water management. This new policy has had a profound effect on the new parks that are being developed in the Town, and there are some long range implications that are evident at this time.

At the outset, I must state that I agree with the basic principle of using storm water management, in that we are able to minimize environmental impacts of new subdivision development. The new policy enables us to blend the new, with the old in a pleasing and practical manner.

What I hope to impart to you today, is a brief outline of some initial concerns, problem areas and benefits derived in Markham over the past 3 years.

The design of storm water management systems has resulted in the parks being perhaps the most important aspects of the system. Since 1977 we have had 9 projects designed with 3 having been installed and maintained for at least one year; 3 having been completed recently this year and 3 are under construction at the present time.

Six of the above utilize the park areas for dry pond purposes; two are ponds with water in them year round; and one(1) is used as a dry pond in combination with an underground "super pipe" for storm water storage.

Initial Concerns

Although we were briefed on the engineering details of this new approach, we had some initial concerns that have been realized in varying degrees.

- My prime concern was the possibility of not being able to use the parks because of lingering wet ground conditions. This appeared to be a natural concern considering that the parks were to be used for "storm water retention". Generally speaking we have not experienced this problem, and 1980 was a very wet year as you will recall. One isolated problem did occur, but with a small redesign, this can easily be solved.

  We have maintained 2 parks for one complete year and have experienced no use problems, other than what we normally would have. I still reserve judgement on a long term basis, however, it would appear that this concern will not be a problem.

- Increased maintenance costs were a concern at the start, which have not yet become a reality. It is difficult to prove, or disprove, that costs are more, or less, than they would have been, however, we have not yet experienced any increased costs in looking after the new park areas.

- Concern with having "outsiders" having a say in the design of new parks. In the past, we have designed our parks from "the parks" point of view. Now we had people whose prime concern was not "parks" but "drainage" having a say in our parks, and to make matters worse, these people were "Engineers".

This initial concern has been borne out to a certain relatively small extent, and I shall outline it later in my comments.

- Conccern that if some park acreage was taken up for storm water management, we would not have enough for parks purposes. This has happened once, and it could be argued that it was not entirely the fault of storm water management.

Benefits

- Contribute to a better overall method of dealing with storm water in a manner that is less harmful to the environment.

- I assume that it is a cheeper method vs traditional storm sewers and any cost savings should result in cheaper housing.

- Less reluctance on behalf of developers to pay for parks development. We are now getting our parks totally developed and this would have taken us several more years to achieve without the impetus of the storm water management.

- Increased amount of open space, in some cases, e.g. pond areas which would not have been developed without storm water management. Any increase in developed open space is an asset to the community.

- Better planning is a reality that has occurred because all of our parks have to be totally planned at the outset, because the grading of the subdivision is done very early in the development process. We are now forced to

plan our parks down to the last detail. Some would say that this might pose problems because once planned it will be difficult to change in the future, but I feel that this detailed planning is a benefit.

PROBLEMS

Park Design and Priorities

At times it appears that some of the consultants designing the storm water system, feel that they are designing a storm water system that may have the side benefit of having some parks use, if there is any land left over. Form my point of view, what we are designing is a park that will have the side benefit of some storm water management purpose, and that in many cases this can be done to everyone's advantage.

Obviously, firm positions as to parks vs storm water will not result in the best possible design or, in the long run, the best service to our residents (and we must remember that our only reason for being in this business is to serve the residents of our communities).

To achieve the best results, it is important that both purposes be planned together, but, since the land is parkland I do not feel that it is unreasonable to expect that the #1 consideration must be the parks' function.

Maintenance Costs

With storm water management, parks maintenance budgets will increase. This increase is not so much with any extra costs of looking after specific park areas, but rather with the extra areas that we have inherited. For example, the landscaping of the 2 ponds that we now have, would not have been there were it not for storm water management' and yet the

maintenance of same is considered to be a parks costs, and not a storm water facility cost. All of this is fine, as long as it is realized that some of the increased parks budgets are as a result of the storm water management programs. This may seem obvious now, but these things tend to be forgotten over the years, and I would hate to see operating funds jeopardized for this important "soft service", as a result of increases in the "hard service" area. This "problem" might be one more of attitude and priority rather than an actual financial one.

These two problems are not major ones as both can and have been resolved fairly easily once they are identified. We are experiencing one problem that is of an ongoing concern.

Quality of Parks Installation

Our only real problem has arisen in the area of the quality of the fine grading and sodding of some (and I stress some) park areas. We insist that all park areas be sodded and unfortunately we have received some very poor jobs. It is hard to understand how everything else in the subdivision is very well done, and yet the last thing, and in many cases the most visible asset in the area, is done in a shoddy and unacceptable manner. The only reason I can come up with is that some people do not consider this to be important, or else more care would be taken.

Because we have final approval of the park, we can and do insist that this be done properly, but it would be so much easier, and less costly if a little more care were taken to do it right in the first place. We have ended up getting a proper job, and we'have found that you certainly do get paid attention to when you refuse to accept 5 or 6 acres of sod that has just been laid.

We have had some excellent work done in the parks, but it has been enough of a problem, that it had to be mentioned.

In summary, our experience to date enables me to state that the use of parkland for storm water management purposes does work and is of a mutual benefit to all concerned. Some problems and long range concerns do exist, however, none of them appear to be so serious that they cannot be overcome by proper attiudes, planning and execution.

DESIGN CASES: HYDROGRAPHS AND SIZING OF STORM WATER DETENTION FACILITIES

by

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ABSTRACT

By way of introduction, the need for runoff control and the applicable criteria are reviewed. The need for hydrograph based techniques, rather than the traditional Rational Method approach, is examined. Selection of a design storm input for such techniques is briefly discussed. A number of methods and models suitable for obtaining pre and post-development hydrographs are presented by means of example of actual applications.

The principle of attenuating flows by use of storage is briefly reviewed. Techniques of sizing storage in both planning and design stages are examined. Design constraints which affect required storage volume are discussed. A number of examples of storm water detention facilities which have been constructed are presented to illustrate the above techniques and constraints.

INTRODUCTION

Before examining techniques for obtaining hydrographs and storage volumes for storm water detention facilities it is beneficial to review a number of basic questions such as:

- "Why do we need runoff control?"
- "What criteria should we use?"
- "Why do we need a hydrograph based method?"

Why Runoff Control?

In the past 20 years there has developed a considerably improved understanding of the urban hydrologic process and the effects of urbanization on water resources. It has been demonstrated that increases in imperviousness, improved drainage networks and loss of storage all lead to increased runoff rates and volumes. As Figure 1 illustrates, runoff volumes can increase as much as 10 to 20 times. Similarly, velocities of overland flow can increase up to 10 times, Figure 2. This has the effect of increasing peak flows by as much as 10 times and also reducing the time to peak flow as indicated in Figure 3.

Without any form of runoff control increased flow can lead to downstream flooding requiring remedial flood protection works and culvert replacements. Existing storm or combined sewer systems may become overloaded requiring relief measures to be carried out. Even in the absence of flood related problems, severe difficulties can arise with respect to erosion of downstream channels. As Figure 4 (Leopold, 1968) illustrates, flows which prior to development only occurred once every two years may occur as often as once every two months after development of an area. Clearly the potential for transport of sediment is vastly increased. In situations where the bank material is susceptible to erosion this can lead to loss of property, silting of reservoirs or channels, destruction of aquatic habitats and the need for costly erosion protection works.

In view of these potential costs it has been recognized as appropriate (M.O.E., 1977) that measures should be taken to minimize increased flows due to urban development.

What Criteria Should Be Adopted for Runoff Control?

Having recognized that runoff control is desirable the first step in any practical application is to determine what criteria are appropriate. Two factors are involved; the size, i.e. return period of the event to be controlled and the degree to which control will be applied. Although both are in fact site and problem specific, general guidelines are frequently applied. Since it is impractical to set individual criteria for each development a regional guideline based on some form of master drainage planning is probably the best solution.

A good example of this approach is that adopted by the Metropolitan Toronto and Region Conservation Authority (MTRCA, 1980a). Flood vulnerable areas within the watersheds under their jurisdiction were identified (MTRCA, 1980b). For all remaining areas the main concern was therefore erosion control. Hence a policy of controlling runoff for the 2 year return period was adopted. This avoids the considerable extra expense of controlling greater flows, say the 100 year event, in areas where this would have little or no benefit.

With respect to the second factor, the degree of control which should be applied, it has become general practice to adopt a policy of "zero runoff increase". This implies that the peak flow after development should be the same as that for pre-development conditions. It has been argued that the degree of control should be on a case by case or on a percentage of post-development flow basis. It would seem, however, that unless a deviation from the "zero increase" policy is justified by a detailed study of the particular situation it remains the most reasonable criteria.

Why Are Hydrograph Based Methods Necessary?

The traditional method of designing urban drainage in North America has been the Rational Method. This simple technique gives estimates of peak flows based on drainage area, rainfall intensity and an empirical runoff coefficient. This is not, however, adequate for designing runoff detention facilities since, in general, storage in some form is used to reduce peak flows. This is a case of the classical "flood routing" problem. In order to estimate outflows from storage an inflow hydrograph, i.e. a trace of the variation of inflow rates with time is required.

Another factor which dictates the need for a hydrograph based method is the requirement for information on the timing of flows within any watershed system. For example, it is entirely possible that runoff control in a downstream area of a watershed or sewer system may be ineffective if the peak flow in the downstream area is delayed sufficiently that it becomes coincident with the peak from upstream areas. The only method of examining such a situation is to compare hydrographs indicating the timing of the flows from each area.

HYDROGRAPH COMPUTATION METHODS

In response to the need for hydrographs of urban runoff and in light of the scarcity of actual flow data in such situations a large number of techniques have been developed for estimating urban runoff. The choice of a particular technique or computer model should be dictated by the type of problem being examined. However, the general approach will be relatively similar and this will be briefly described. Two specific computer models will then be briefly discussed in the context of an application which has resulted in the construction of a storm water detention facility.

In its most general form the derivation of a runoff hydrograph consists of the transformation of an input "design" rainfall into an "effective" precipitation by subtracting infiltration and surface storage losses. This "effective" precipitation is then routed overland or through a sewer system to produce a hydrograph at the point of interest.

The first problem in this process is to select the "design" rainfall. This choice is critical since it has been demonstrated (IMPSWM, 1979) that different assumptions can lead to very different flow estimates for a given system. As Figure 5 indicates, two commonly used distributions i.e. the SCS Type II (S.C.S., 1975) and the "Chicago" storm (Kiefer and Chu, 1957) have very different patterns. The peak intensities for the two "5 Year Storms" are 2.7 and 4.5 inches per hour respectively. Various attempts have been made to determine the most suitable "design" storm but as yet no definitive guidelines exist and experience is required in this selection.

The next phase in the process is to collect sufficient background information from which to calculate parameters required for the selected hydrograph method. Typical requirements are topographic maps of the area and drainage paths before development, soils and land use information before development and grading and sewer plans (if available) after development. The required parameters are usually of two types; those relating to "losses" such as SCS Curve Numbers (SCS, 1972) or Horton's infiltration parameters (Horton, 1940) and those relating to timing such as time of concentration or basin lag time. For a simple manual technique such as that described in the SCS TR55 manual (S.C.S., 1975) these parameters are used in a series of charts and tables to obtain approximate hydrographs. For more complex computer based techniques these parameters together with a description of the physical system are used to simulate the rainfall-runoff response of the area.

A typical example which illustrates the use of the computer models SWMM (Huber et al., 1975) and HYMO (William and Hann, 1973) is the Markville development in the Town of Markham. The development will consist of 180 acres of residential and commercial land use. The criteria applicable in this particular case was control to pre-development levels of flows up to and including that from the 100 year storm. Figure 6 shows the drainage basin, the sewer system, overland flow paths and the schematization of the area used in the modelling.

Pre-development hydrographs for the area were obtained using the HYMO model developed by the U.S. Department of Agriculture. It is based on the SCS runoff volume estimating technique in which tables have been developed relating soil type and land use to runoff potential as expressed by a Runoff Curve Number (CN). For the Markville area a pre-development CN of 79 was estimated. This is relatively high giving about 30% runoff from a 2 year rainfall. The drainage area was divided into a number of sub-areas and the parameters of the unit hydrograph for each area estimated from empirical equations included with the model. The resulting hydrograph with a peak flow of 16 cfs for a 2 year storm is shown in Figure 7.

In common with many such applications details of the storm drainage system after development were not available at the start of this study. Initially therefore a sewer system was designed using the Rational Method. Since this provides only peak flow estimates at any point the developed area was then modelled using the U.S. E.P.A. Model SWMM. This model has gained wide acceptance as a tool for simulating the behaviour of urban drainage systems. The drainage area is divided into sub-areas and a mathematical representation is prepared for each using

parameters such as area, imperviousness, surface roughness and slope. Using the Horton's infiltration equation and the kinematic wave approximation to overland flow, hydrographs are computed from the input design storms. In the past-development condition it was estimated that the volume of runoff from a 2 year storm would increase to about 55% of the rainfall. Combined with a greatly reduced time of concentration this results in a peak flow of 140 cfs and a hydrograph as shown in Figure 7. This is almost an 800% increase from the estimated pre-development flow.

CONTROL OF STORM RUNOFF USING STORAGE

The use of storage in controlling flood flows on rivers is a long accepted and widely practiced technique. Its application in storm water management on a more local scale is more recent. The classical techniques of reservoir routing can be applied in the analysis of such applications.

The effect of storage is to attenuate the incoming flood wave, i.e. to reduce and delay the peak flow.

In the storm water management situation two types of storage facilities i.e. on-line and off-line are applicable. In the former case all flows are directed to the unit and are controlled by some form of outlet structure. There will normally be a permanent pool of water in such a facility. In the latter case storage is only utilized above some threshold flow level. Inflow may be controlled by a side weir or may only operate when the storm sewer system reaches some surcharge level. The facility will only contain water during and after severe rainfalls and will normally be dry.

Three methods of determining the required volume of storage may be applicable. Two of these techniques, namely empirical formulae or charts and the graphical technique, are useful in the planning stage when an approximate volume is required. The third technique i.e. reservoir flood routing should be used during the conceptual design stage to fully examine the implications of all design conditions and constraints.

Empirical formulae or charts

A number of authors have presented formulae or design charts from which approximate storage volumes can be derived knowing the characteristics of the inflow hydrograph. One such chart is presented in the SCS Manual TR55 (SCS, 1975) assuming average characteristics for typical outlet structures. A useful formula was presented by Wycoff and Singh (1976):

$$\frac{Vs}{Vr} = \frac{1.291\ (1 - Qo/Qi)^{0.753}}{(Tp/T_B)^{0.411}}$$

Where
- Vs = volume of storage required
- Vr = volume of runoff estimated
- Qo = desired peak outflow
- Qi = estimated peak inflow
- Tp = time to peak of inflow hydrograph
- T_B = base time of the inflow hydrograph, estimated as from the beginning of the rise of the hydrograph to a point on the recession limb at which the flow is 5% of the peak flow.

This formula has proved to be quite accurate provided certain restrictions outlined in the original paper with regard to the ratios $Tp:T_B$ and Qo:Qi are respected.

Graphical Approach

An estimate of storage volume can be obtained by plotting the inflow hydrograph and measuring the area between this curve and an assumed outflow hydrograph. For an off-line unit a horizontal line at the desired peak outflow may suffice. For an on-line storage unit, an additional amount of say 20 percent can be added to allow for the true shape of the outflow hydrograph rising limb. Alternatively a linear flow increase from zero to the desired peak outflow may be assumed. From reservoir routing theory it is known that the peak outflow must be located on the recession limb of the inflow hydrograph.

Reservoir Flood Routing

It is emphasized that the above methods provide only an approximate method of determining storage volume. In order to determine a final volume the inflow hydrograph should be routed through the storage using actual stage-discharge and stage-storage curves. Any constraints, such as restrictions in side-slopes, will be reflected in these curves. This may lead to less than an optimum stage-storage curve and result in a greater total storage requirement than a preliminary estimate may have indicated.

Reservoir routing is based on the equation of continuity,

$$I - O = S/t$$

Where I = inflow rate

O = outflow rate

and S/t = rate of change of storage.

This can be rearranged and expressed in finite differences as,

$$\bar{I} + \left(\frac{S_1}{t} - \frac{O_1}{2}\right) = \left(\frac{S_2}{t} + \frac{O_2}{2}\right)$$

where $\bar{I}$ is the average inflow in a time step

and subscripts 1 and 2 refer to the start and end of the time step.

These equations can be expressed graphically for a given case and manual routing of the inflow hydrograph can be performed. Alternatively a programmable calculator or a computerized version such as in the program HYMO can be used. Whichever method is adopted it is necessary to assume a stage-discharge and stage-storage curve for the facility. If after the routing has been performed the desired outflow peak has not been met then adjustments must be made to these curves and the procedure repeated. Figure 7 illustrates a typical relationship between an inflow hydrograph and a routed outflow.

Design Examples

A number of storm water detention facilities have recently been installed in Canada. Examples in the Toronto area will be discussed to illustrate a number of constraints which should be considered in selection of the final design storage volume.

Flows from the Markville development discussed earlier were controlled by installation of an on-line "wet" pond with a storage volume of about 11 acre-ft. The surface area is between 4 and 5 acres. (See Plate 1) It is designed to control all flows up to the 100 year event effecting a reduction in peak outflow from 400 cfs to 155 cfs for that event. In this case a relatively simple outflow structure consisting of a rectangular notch weir (See Plate 2) was sufficient to provide the desired storage-discharge curve shown in Figure 8. It is also interesting to note that the storage pond was located within the floodplain of the receiving stream on land which could not be developed for other purposes. (See Plate 3)

A facility to be located in the L'Amoreaux Steeles district park in the Borough of Scarborough illustrates two points. This planned "wet" facility will control runoff from approximately 1040 acres of development for storms up to and including the 100 year event. Initial estimates indicated a required storage of 46 acre-feet. However, because of the need for considerable storage at low stages in order to control more frequent flows such as the 5 year return period, the storage-discharge curve is not optimal for the 100 year event. In addition, the facility will consist of 3 cascading storage units. As has been noted by previous authors (Wycoff and Singh), 1976) this is less efficient than a single unit. This has resulted in a final design storage requirement in the order of 65 acre-feet, almost a 50 percent increase over the "ideal" case.

The need to obtain considerable storage at low stages for control of fairly frequent flows while also providing for control of less frequent flows has led to the design of several unique outlet works. In one example (See Plate 4) at the "Canada Wonderland" Theme Park a 9 acre pond with a storage of almost 50 acre-feet has a storage-discharge curve shown in Figure 9. Low flows are passed through a culvert to maintain riparian flow. Flows up to the 100 year

event are passed through an inverted triangular V-notch. At this point there is a horizontal overflow wier which will safely pass flows up to the Regional Storm. (See Plate 5) An outlet with variable geometry at several elevations also controls the facility located in Northeast Markham. (See Plate 6)

Two examples of dry detention facilities are located in the northwest part of the Borough of Scarborough. These units are designed to protect the sewer system from excessive surcharging. Inflow occurs when flow in the sewer is above a certain depth at which time a side flow weir comes into operation. (See Plate 7) In one case the facility is incorporated into an attractive local park. (See Plate 8) In the other example the facility is located in a Hydro easement and utilizes land which could not be developed for any other purpose. (See Plate 9)

The final example is of a total storm water management system installed and operating in the Risebrough developments in the Town of Markham. In this case a system of underground storage units control events up to the 5 year return peiod. At this point overflow occurs into a series of "dry" detention facilities by surcharge from the sewers. (See Plates 10 and 11) Overland flows in excess of the sewer system capacity are also directed to these "dry"ponds. (See Plate 12) In a total drainage area of about 270 acres underground storage to a total of about 5 acre-feet was required. Park storage of about 10 to 12 acre-feet was designed to control the higher flows. (See Plates 13 and 14) For such a scheme a total system analysis was required. Simulation of flows using the SWMM and EXTRAN models were necessary, analysis of overland flows, catchbasin capacities and inlet controls were also required. Detailed analysis of the response of the storage units was also necessary.

Author's note: A large number of slides of the storage units discussed above were used to illustrate this paper at the time of presentation. These could be viewed by arrangement. Tours of the facilities could also be organized if sufficient interest was expressed.

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Wycoff, R.L. and V.D. Singh, 1976: "Preliminary Hydrologic Design of Small Flood Detention Reservoirs", Paper No. 76009, Water Res. Bull, AWRA.

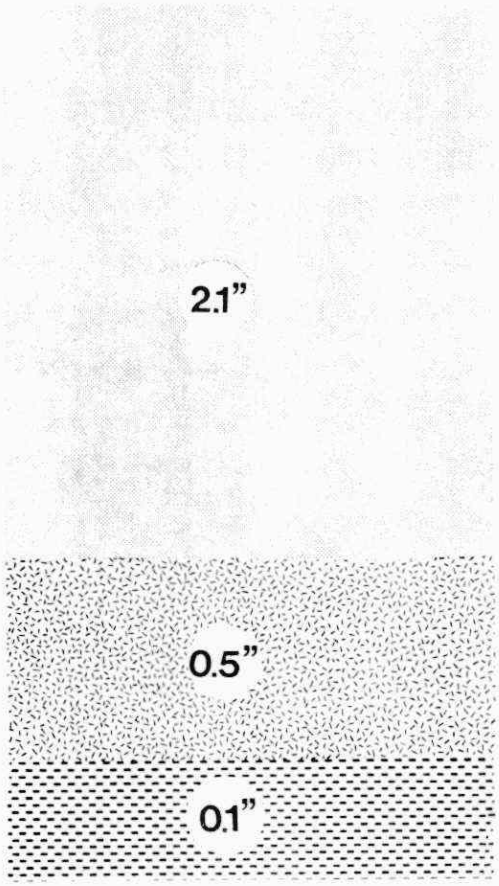


Figure 1:
Run off Volumes 2 Year Rain

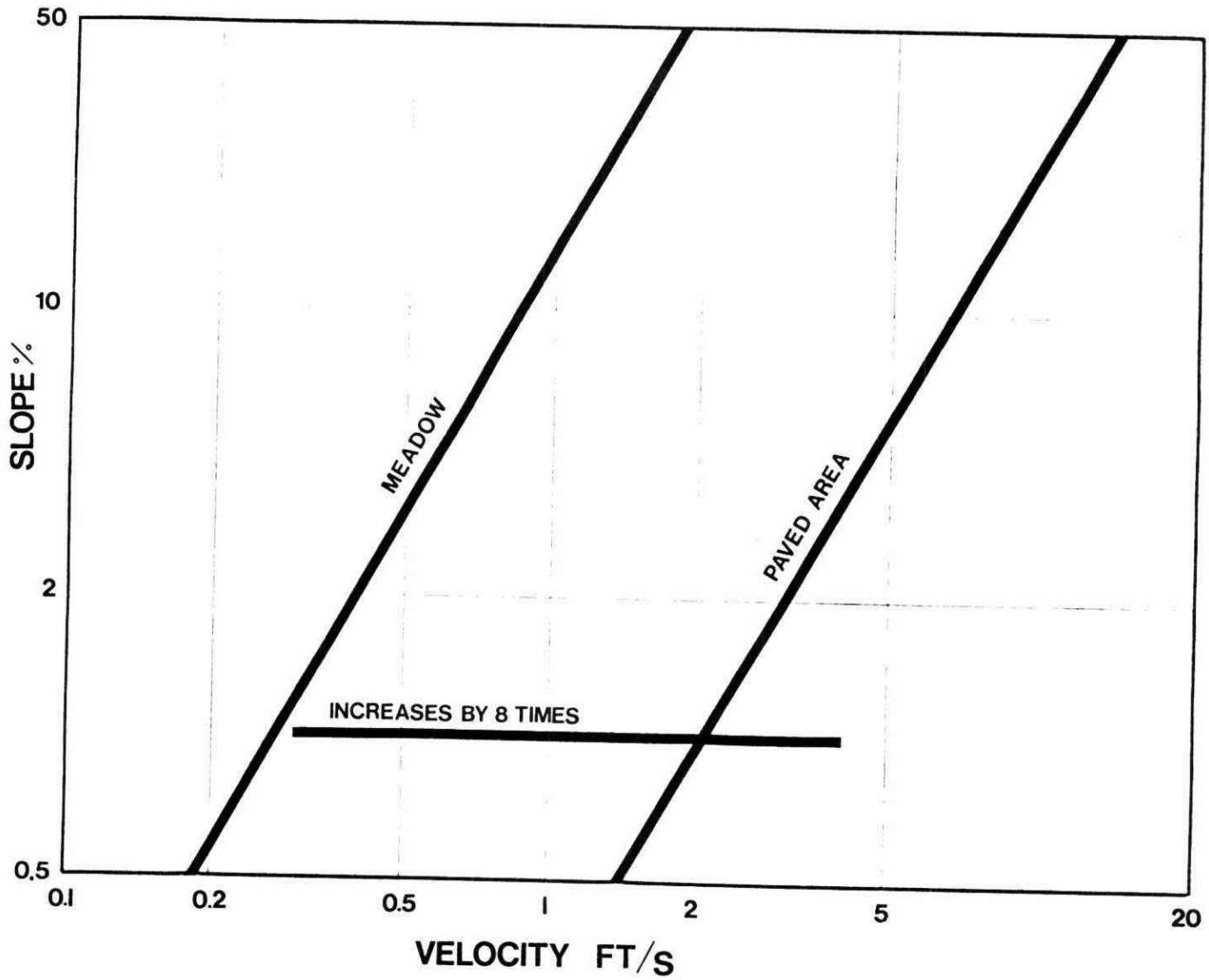


Figure 2:
Average Velocities for Overland Flow

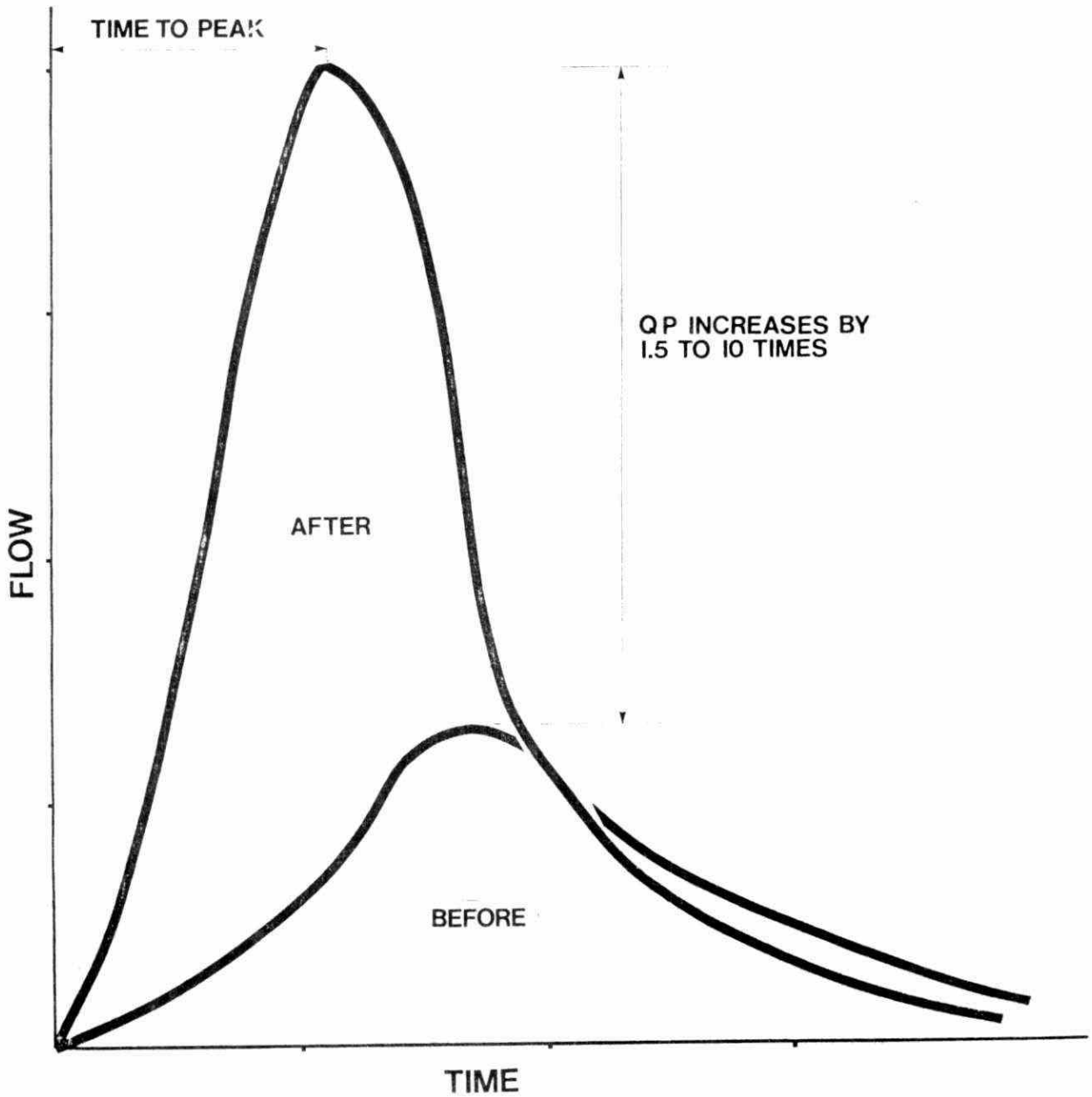


Figure 3:
Typical Hydrographs Before and After Development

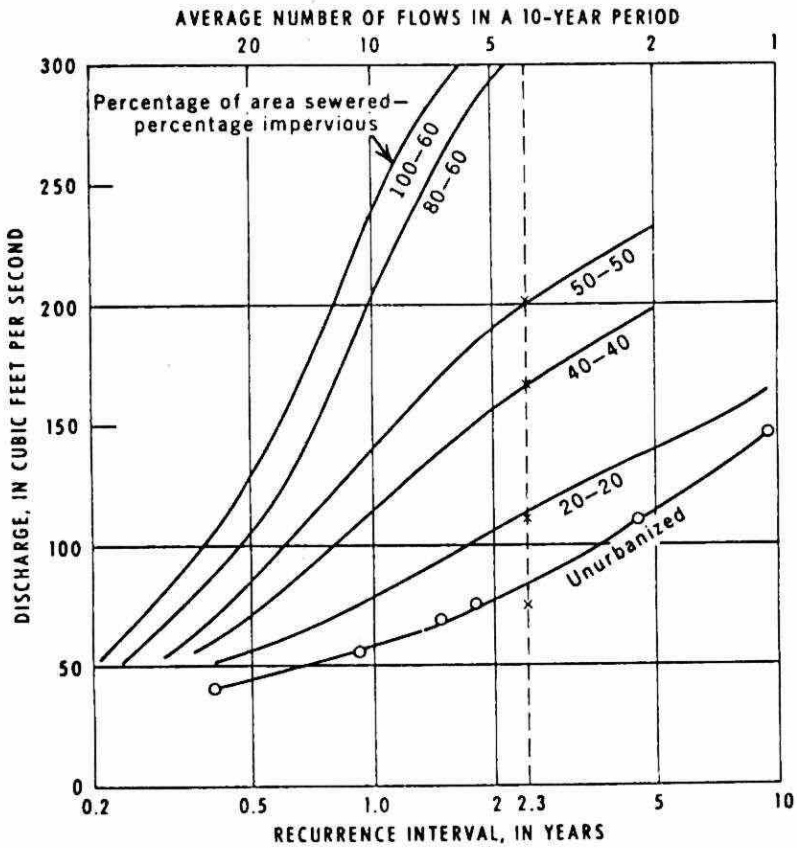
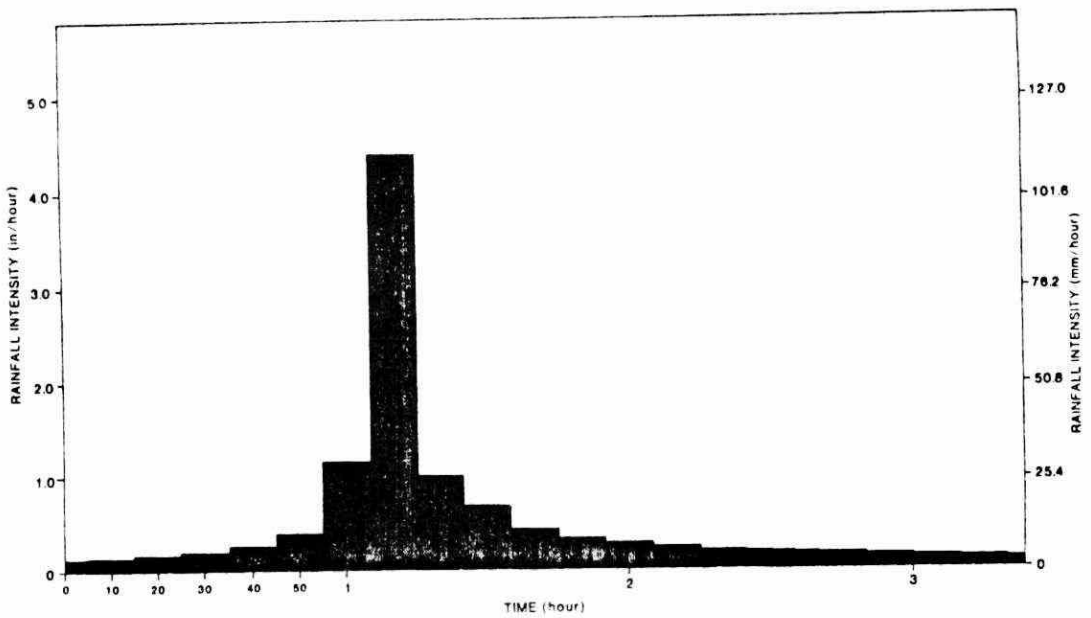
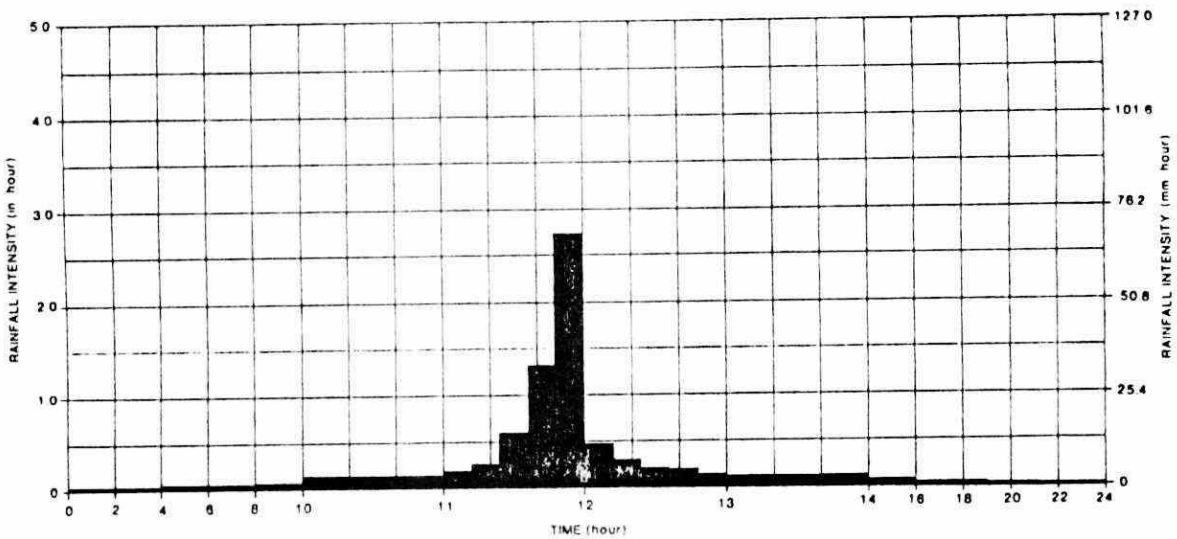


Figure 4:
Variation of Flood Frequency Curves with Urbanization

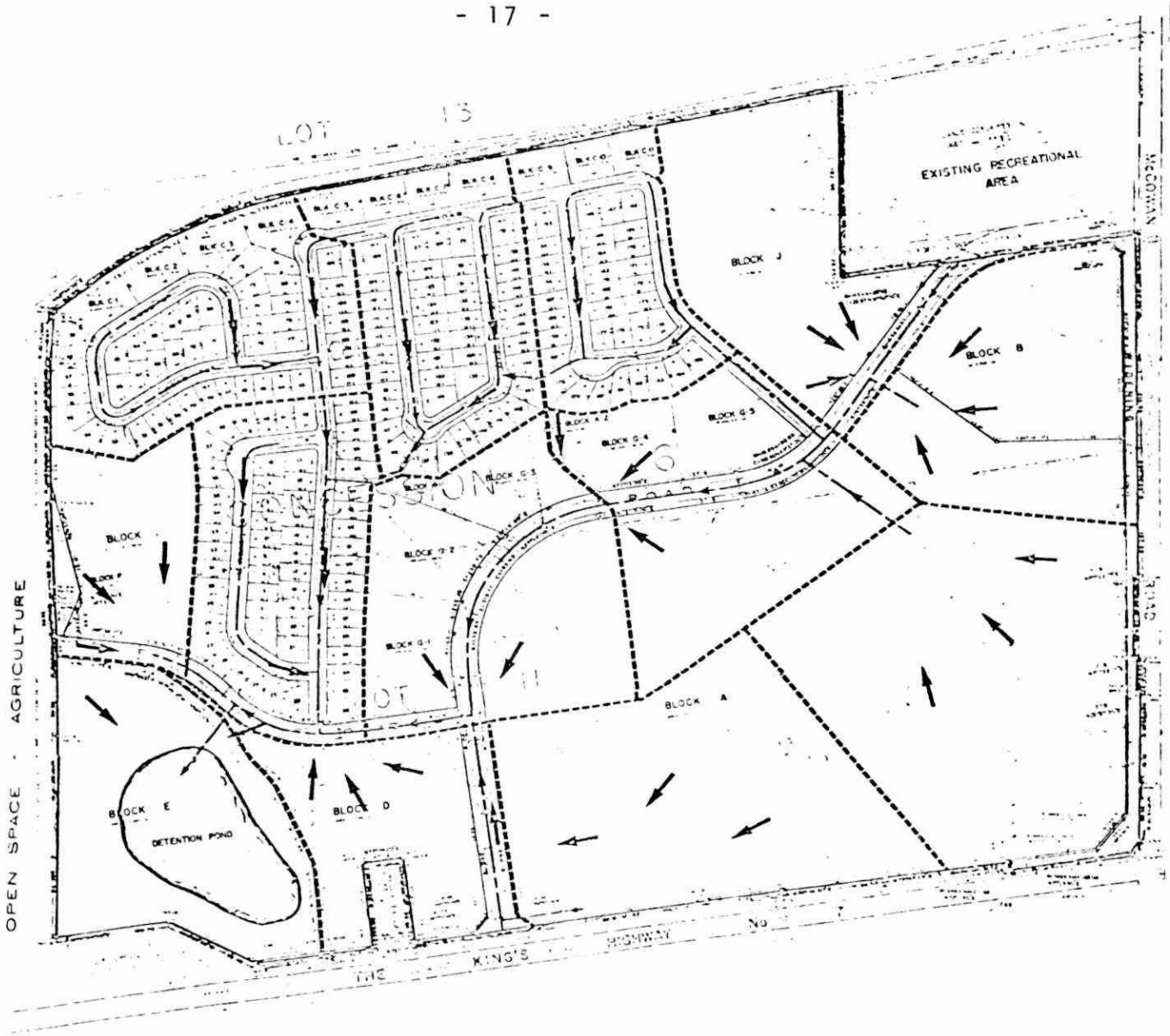


1/5 YEAR DESIGN STORM - CHICAGO DISTRIBUTION



1/5 YEAR DESIGN STORM - SCS TYPE II DISTRIBUTION

Figure 5:
Examples of Design Rainfalls



Legend

--- subarea boundary

→ overland flow direction

———pipe system

Figure 6:

DRAINAGE AREA CHARACTERISTICS & MODELLING SCHEMATIZATION FOR MARKVILLE DEVELOPMENT

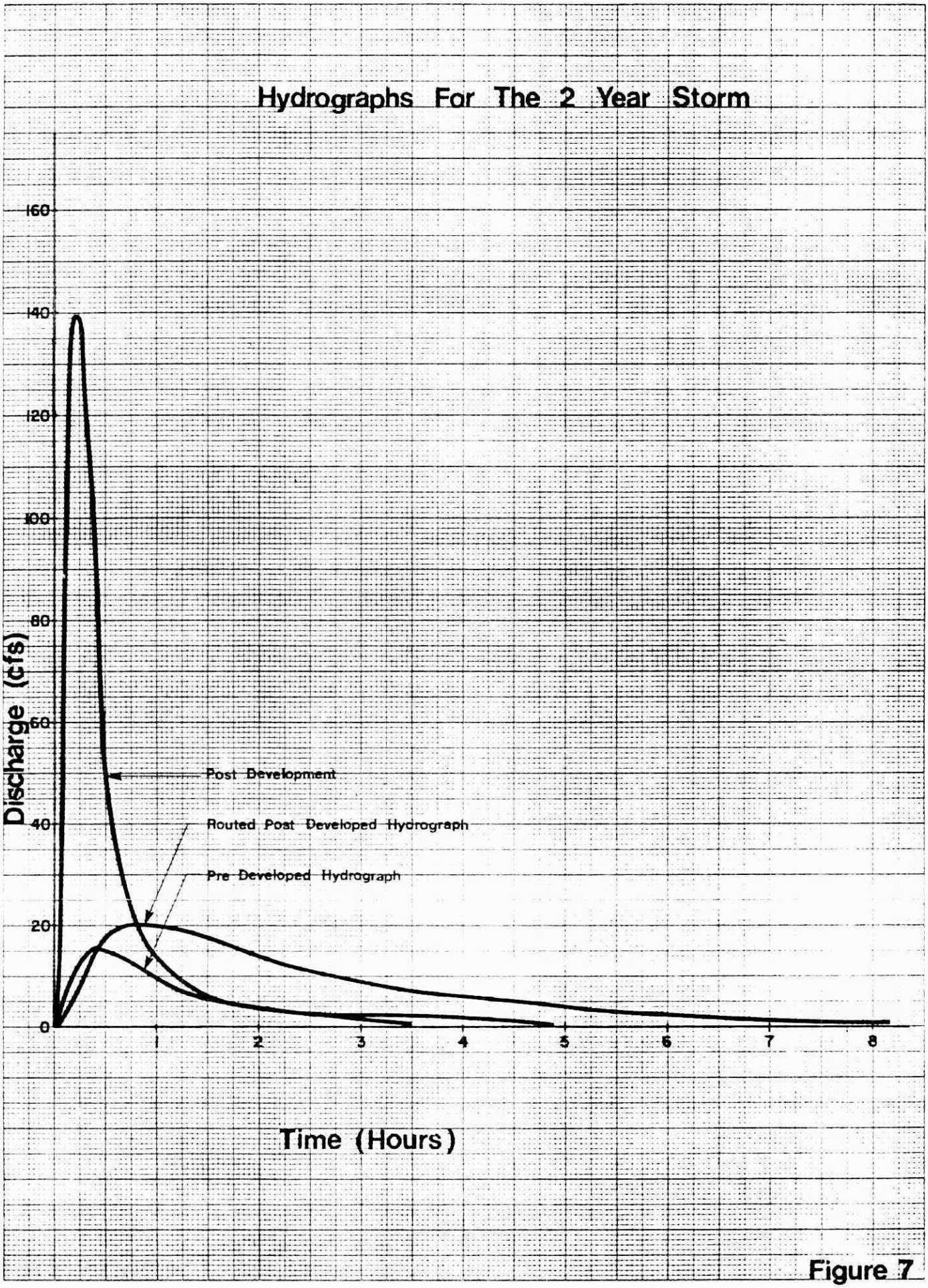

Hydrographs For The 2 Year Storm
160
140
120
100
80
60
40
20
0
Discharge (cfs)
Post Development
Routed Post Developed Hydrograph
Pre Developed Hydrograph
1
2
3
4
5
6
7
8
Time (Hours)

Figure 7

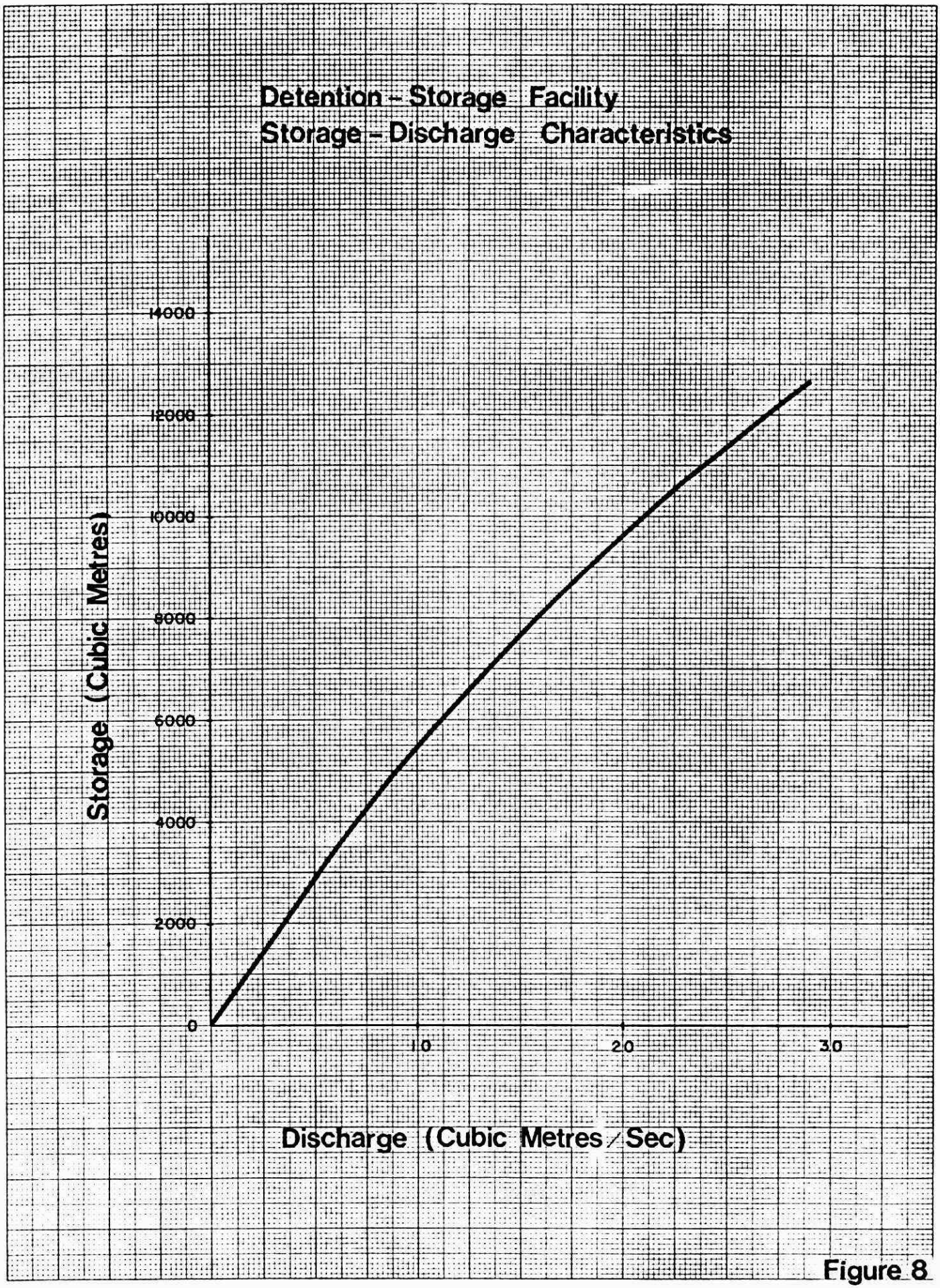

Detention – Storage Facility
Storage – Discharge Characteristics
Storage (Cubic Metres)
14000
12000
10000
8000
6000
4000
2000
0
1.0
2.0
3.0
Discharge (Cubic Metres / Sec)

Figure 8

Storage - Discharge Relationship
South Detention Pond

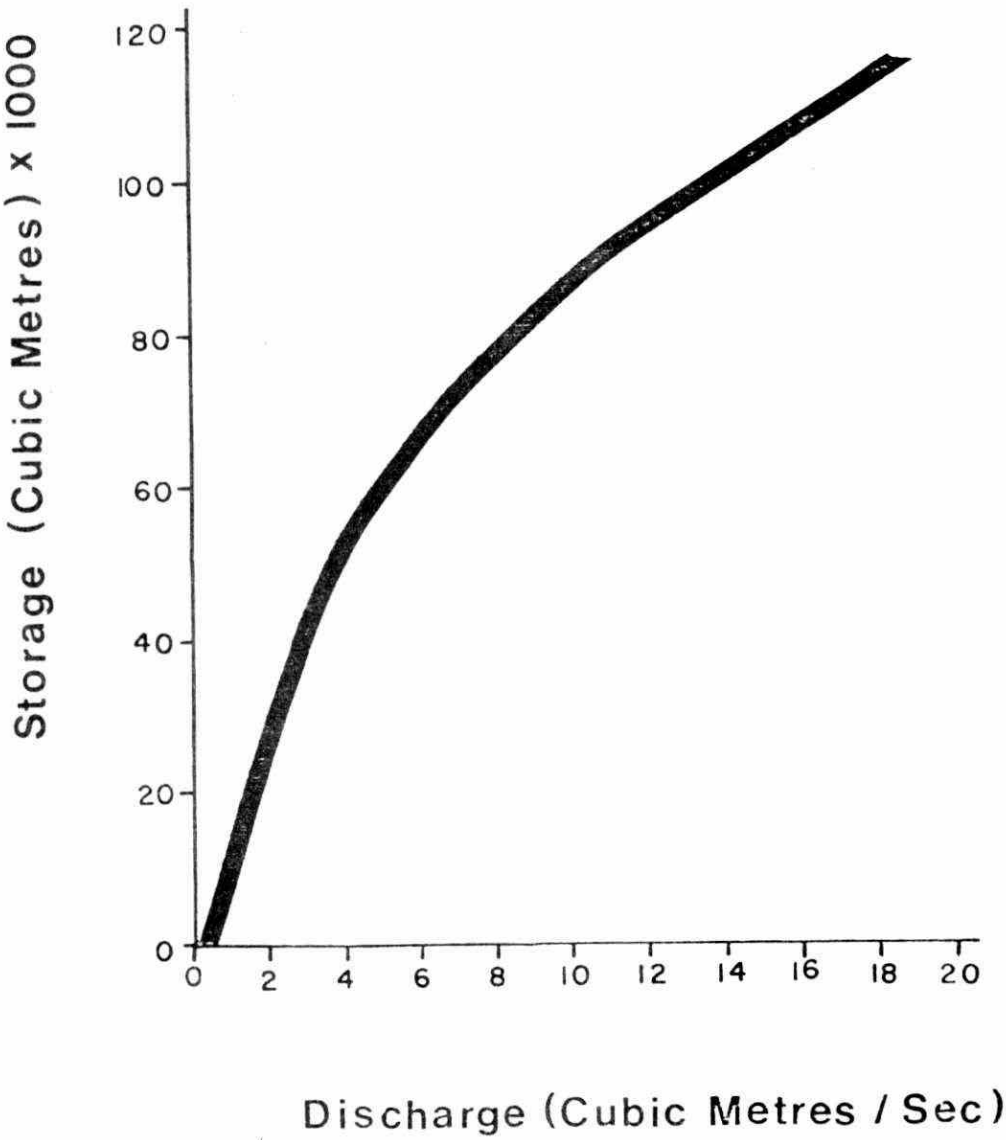


Figure 9

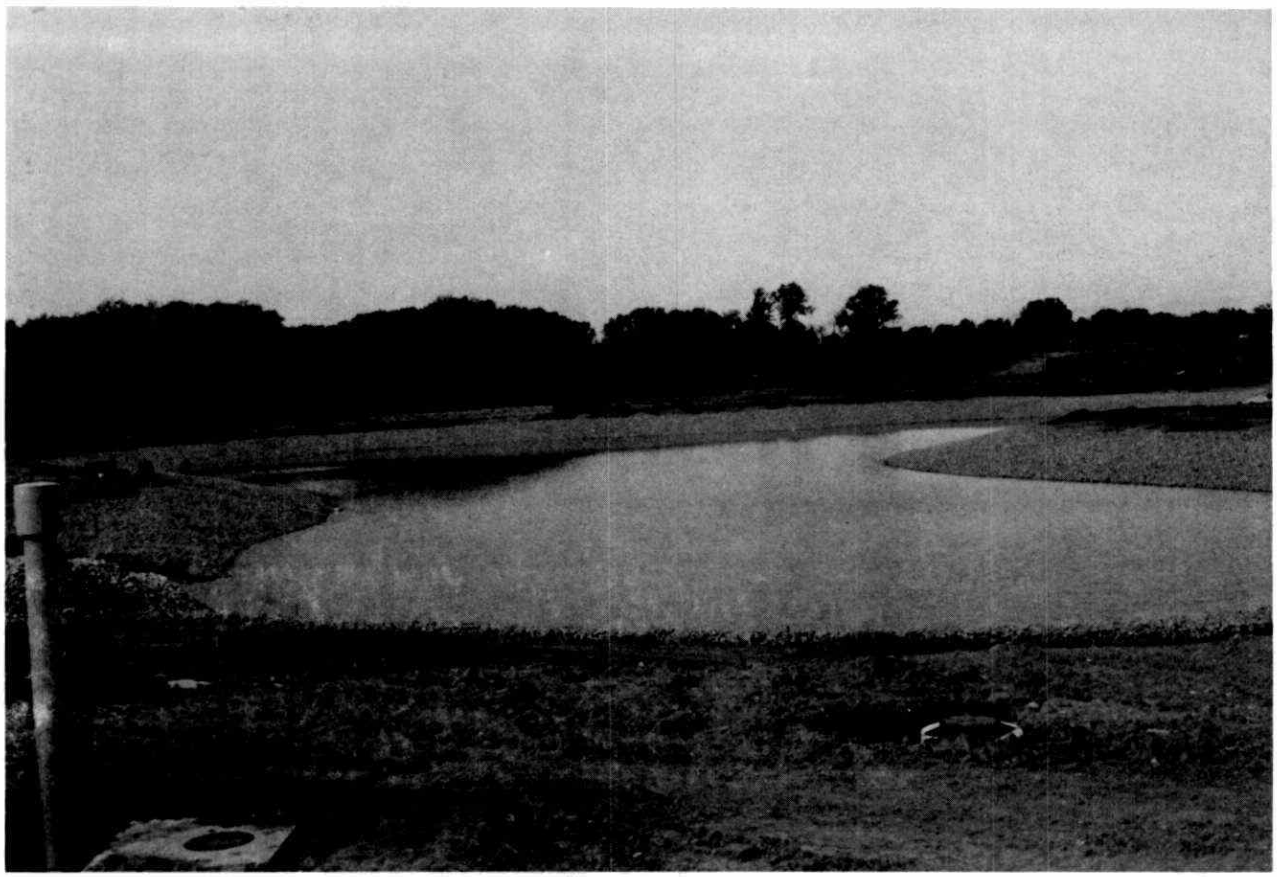


PLATE 1: GENERAL VIEW OF SWM POND
MARKVILLE

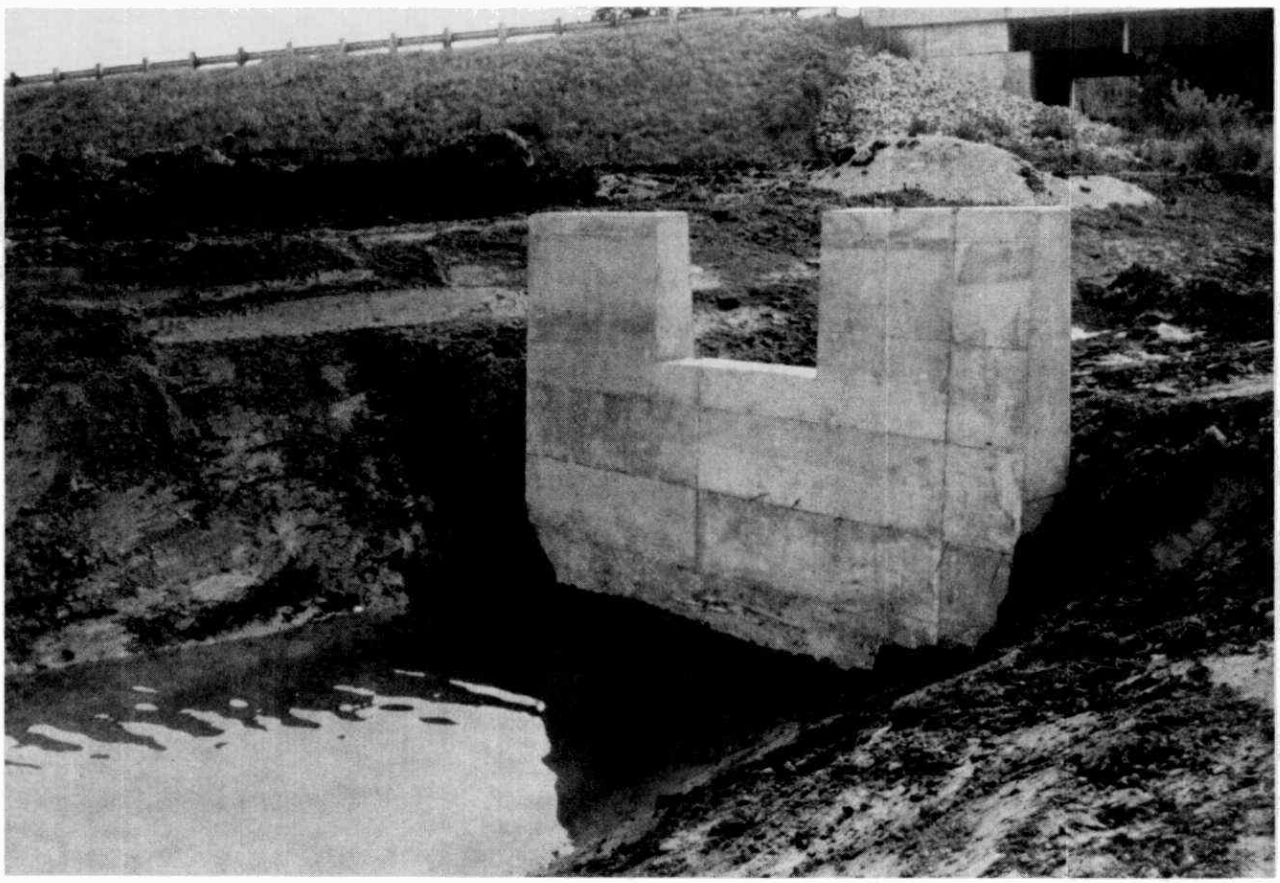


PLATE 2: CONTROL STRUCTURE
MARKVILLE

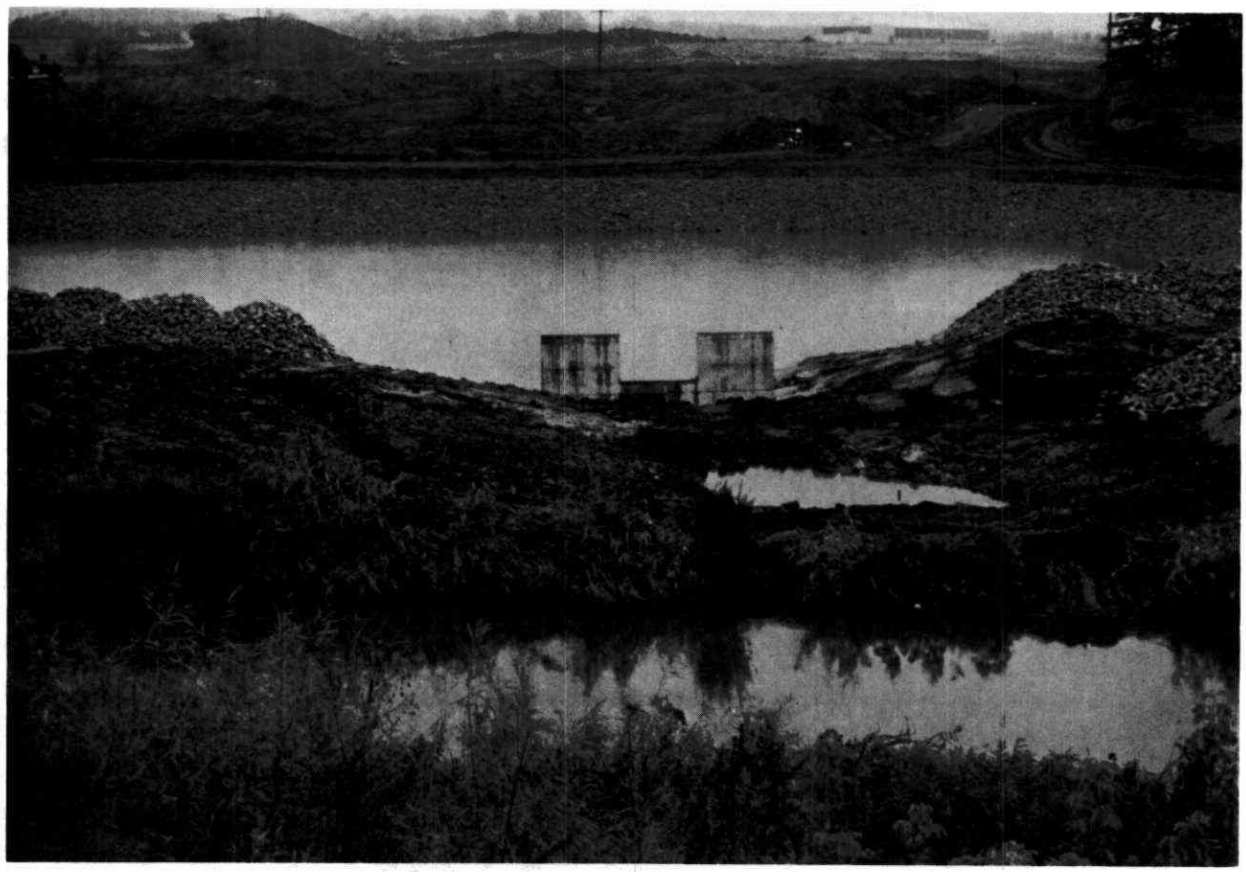


PLATE 3: RELATIONSHIP OF SWM POND TO RECEIVING STREAM
MARKVILLE

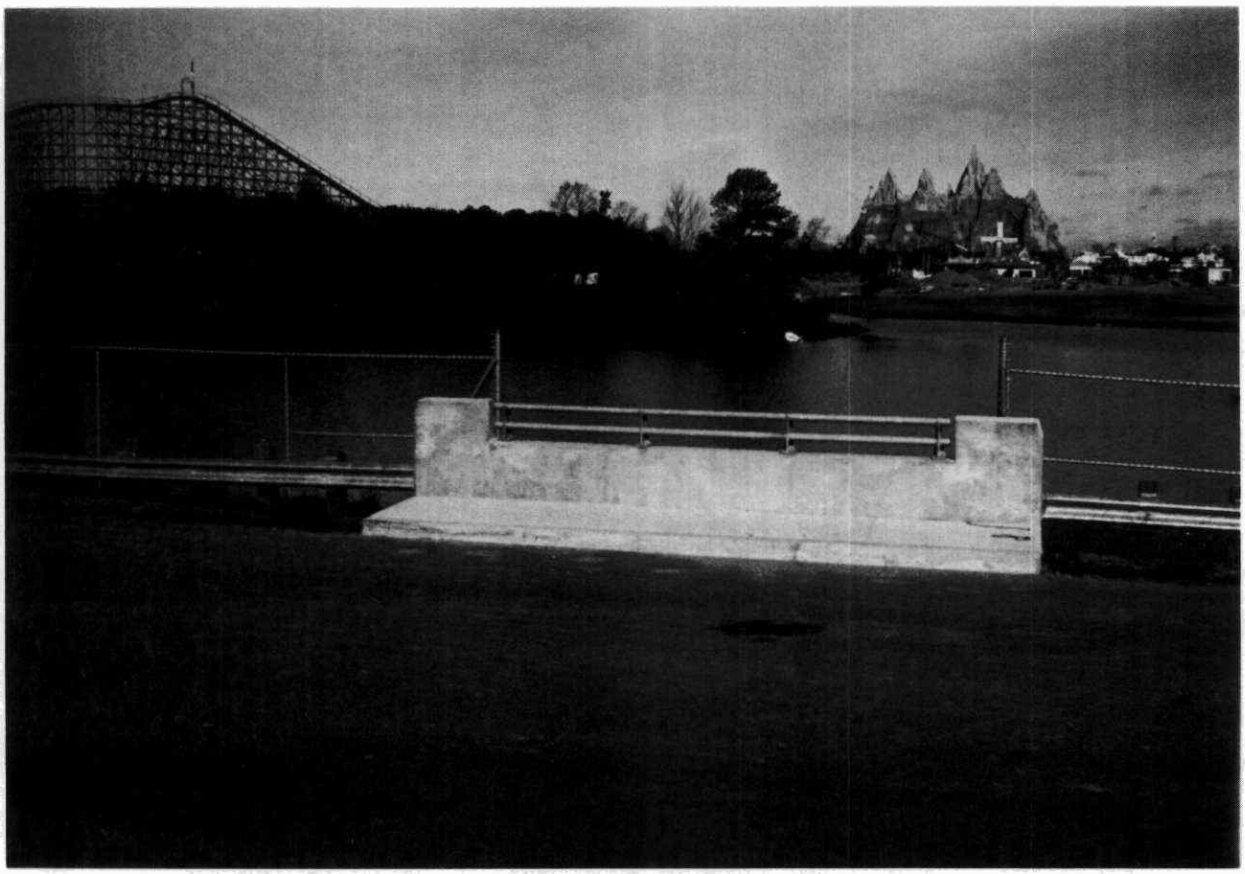


PLATE 4: GENERAL VIEW OF SWM POND
CANADA'S WONDERLAND

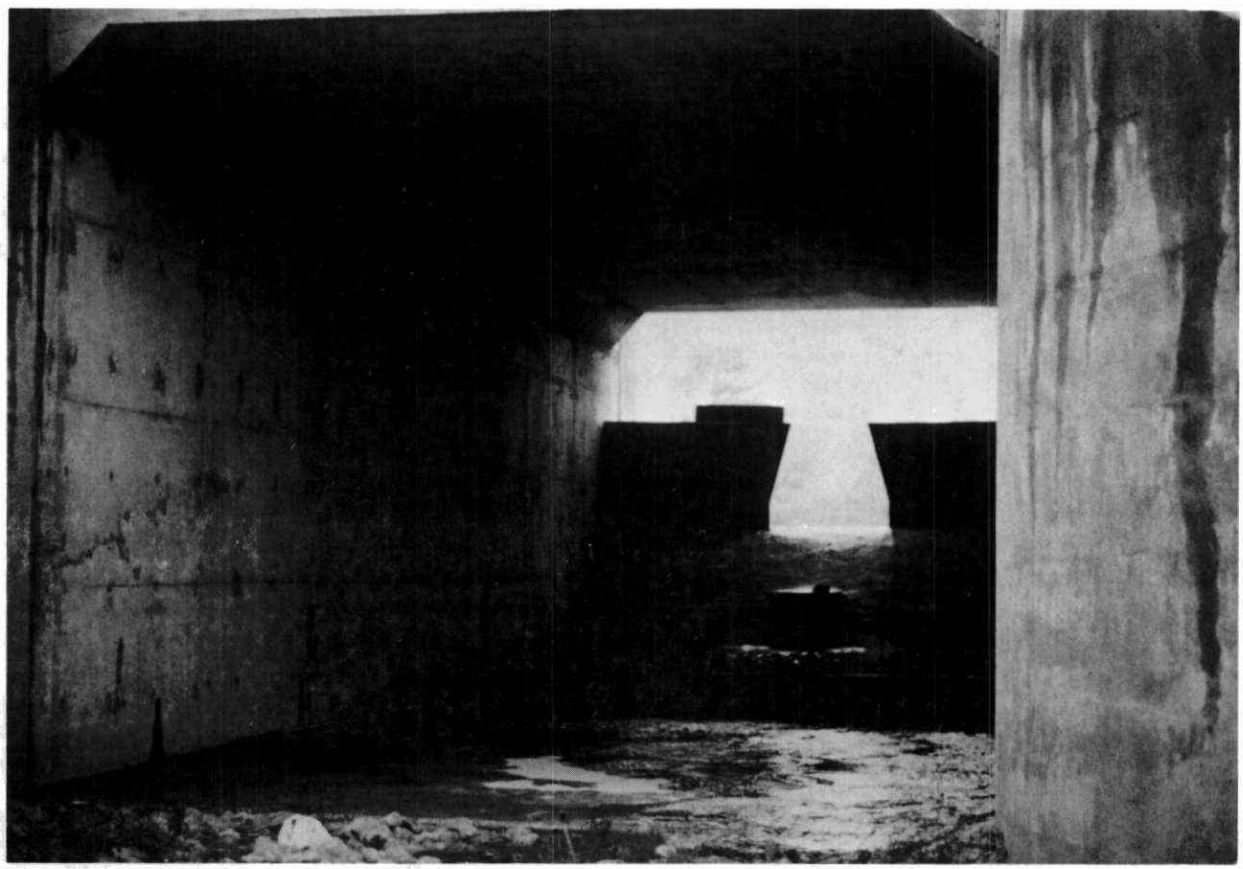


PLATE 5: CONTROL STRUCTURE
CANADA'S WONDERLAND.

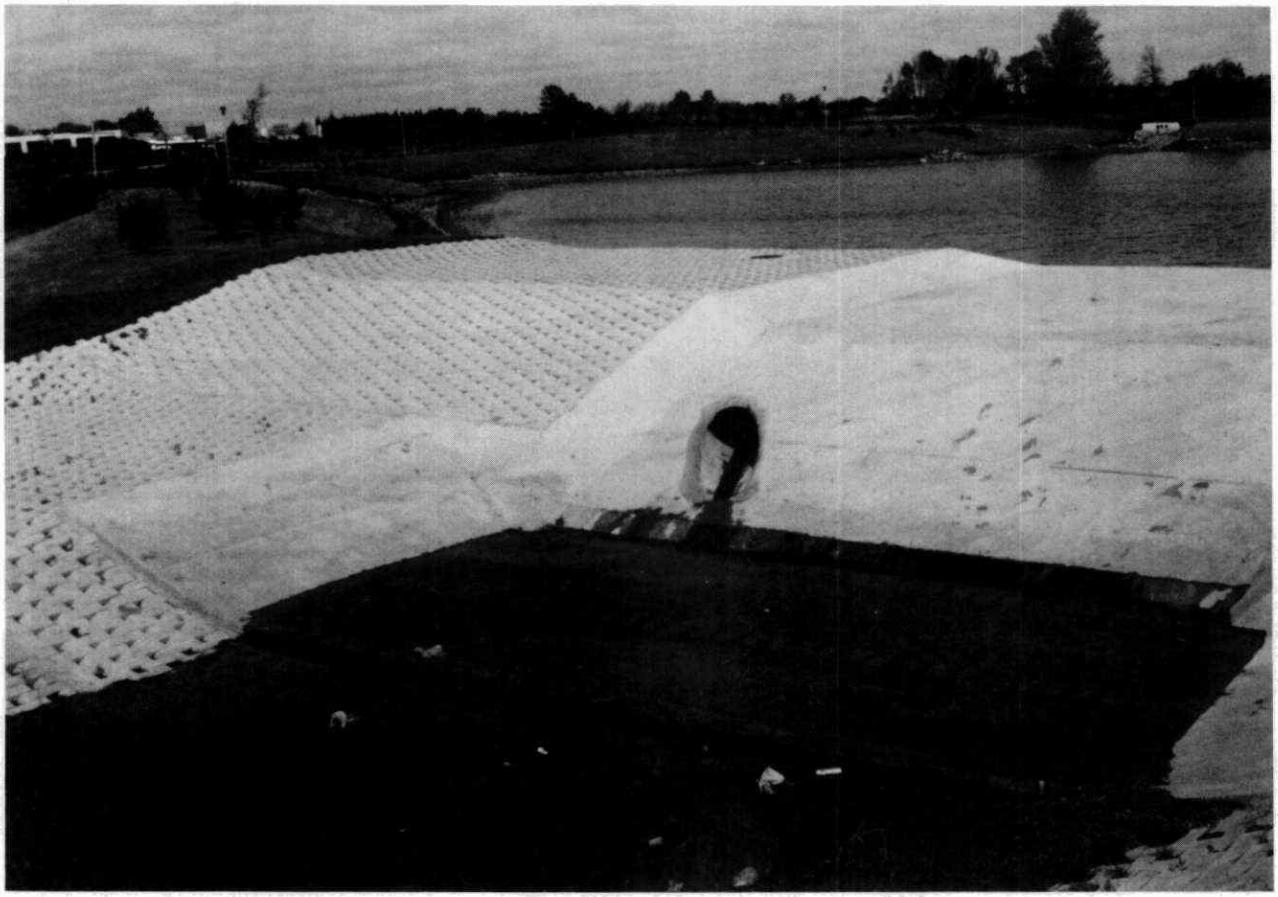


PLATE 6: CONTROL STRUCTURE
EXHIBITION LAKE, N.E. MARKHAM

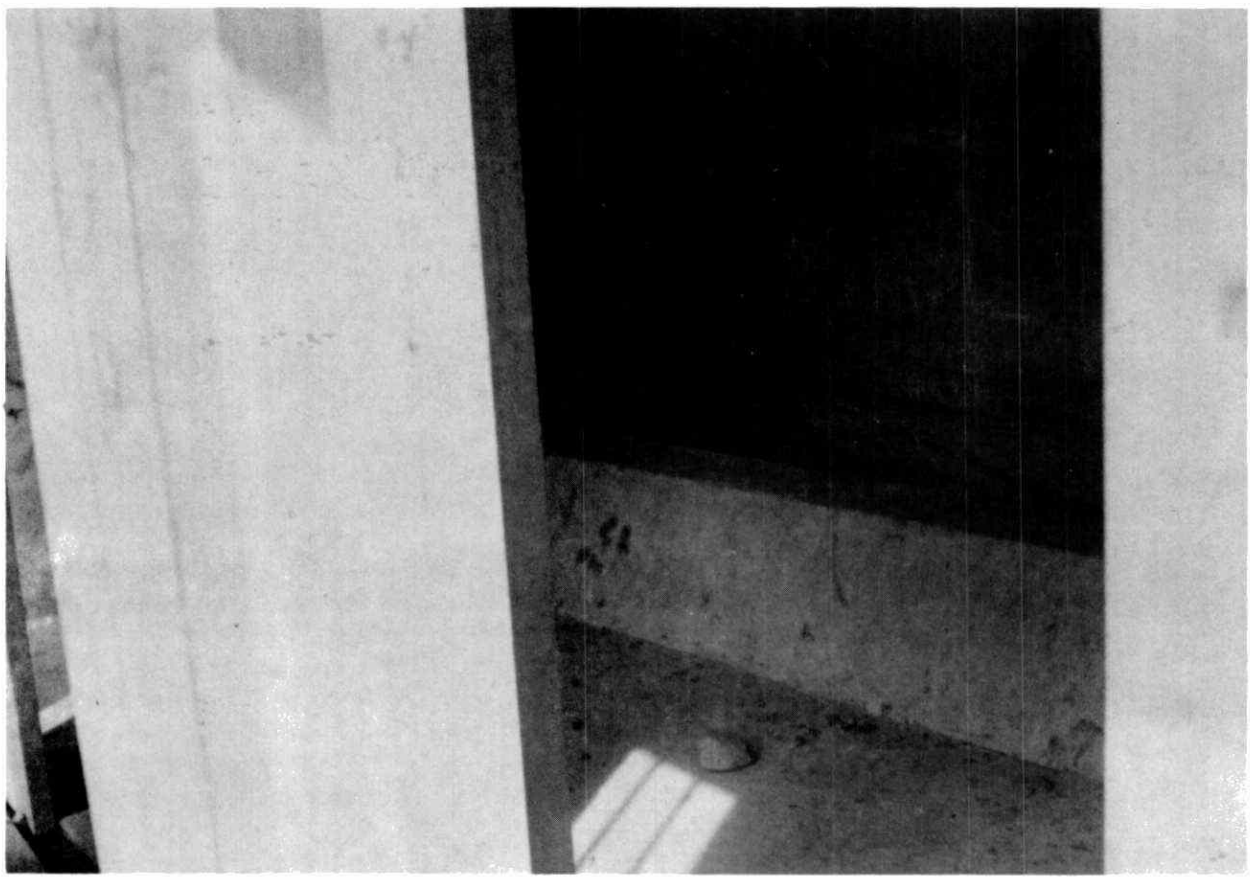


PLATE 7: INFLOW CONTROL STRUCTURE
DRY POND, BOROUGH OF SCARBOROUGH

PLATE 8: GENERAL VIEW OF DRY POND
BOROUGH OF SCARBOROUGH

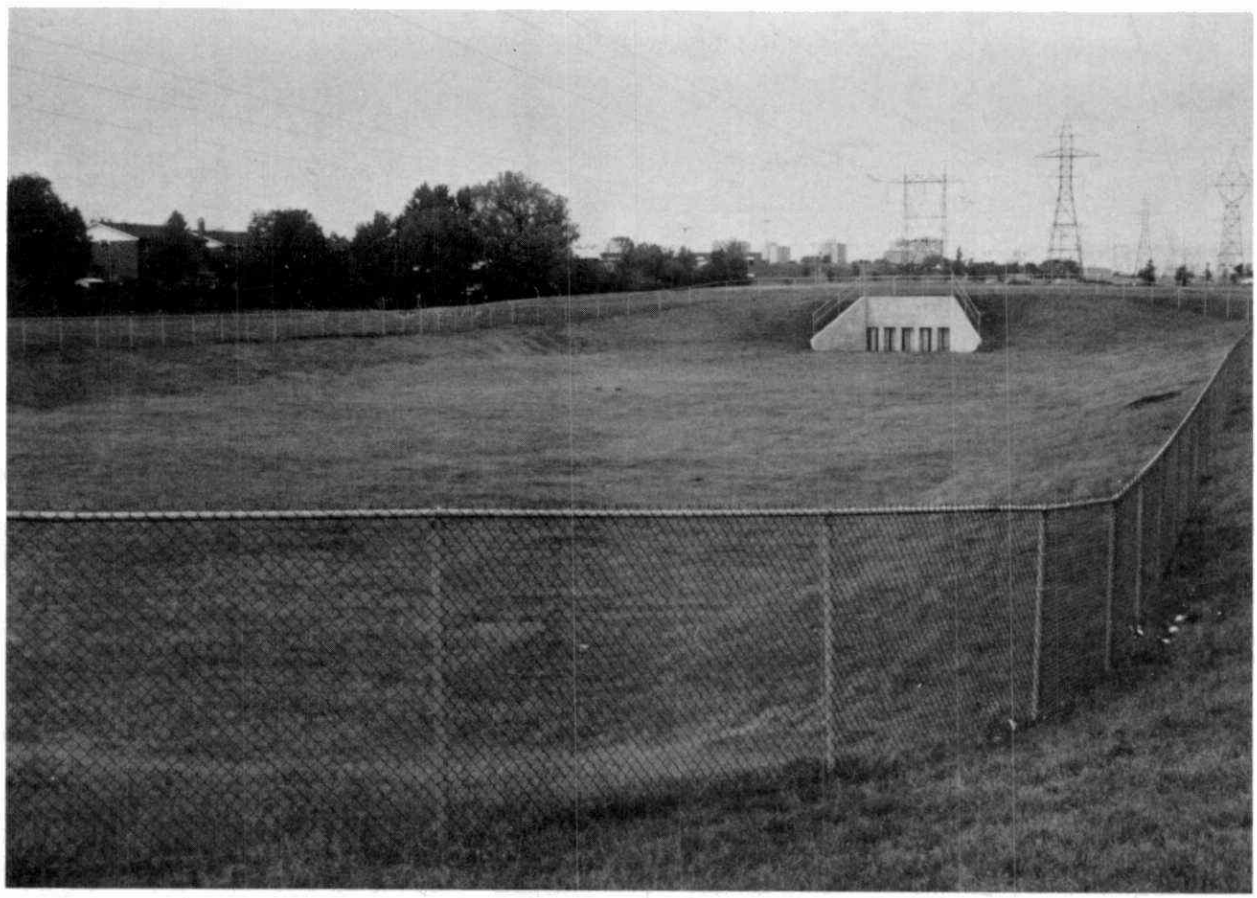


PLATE 9: GENERAL VIEW OF DRY POND II
BOROUGH OF SCARBOROUGH

PLATE 10: GENERAL VIEW OF DRY POND
W. RISEBROUGH, MARKHAM

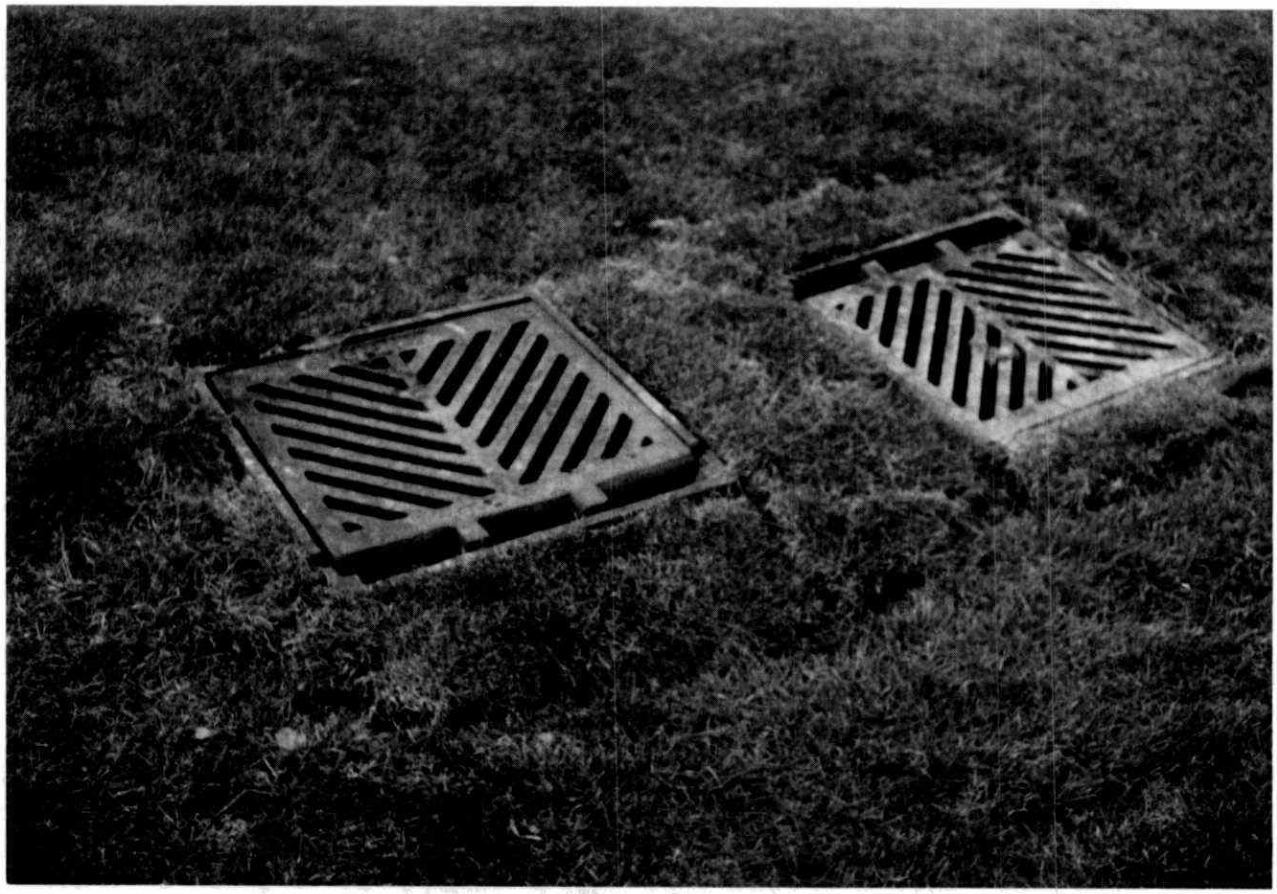


PLATE 11: OVERFLOW INLET/OUTLET
W. RISEBROUGH, MARKHAM

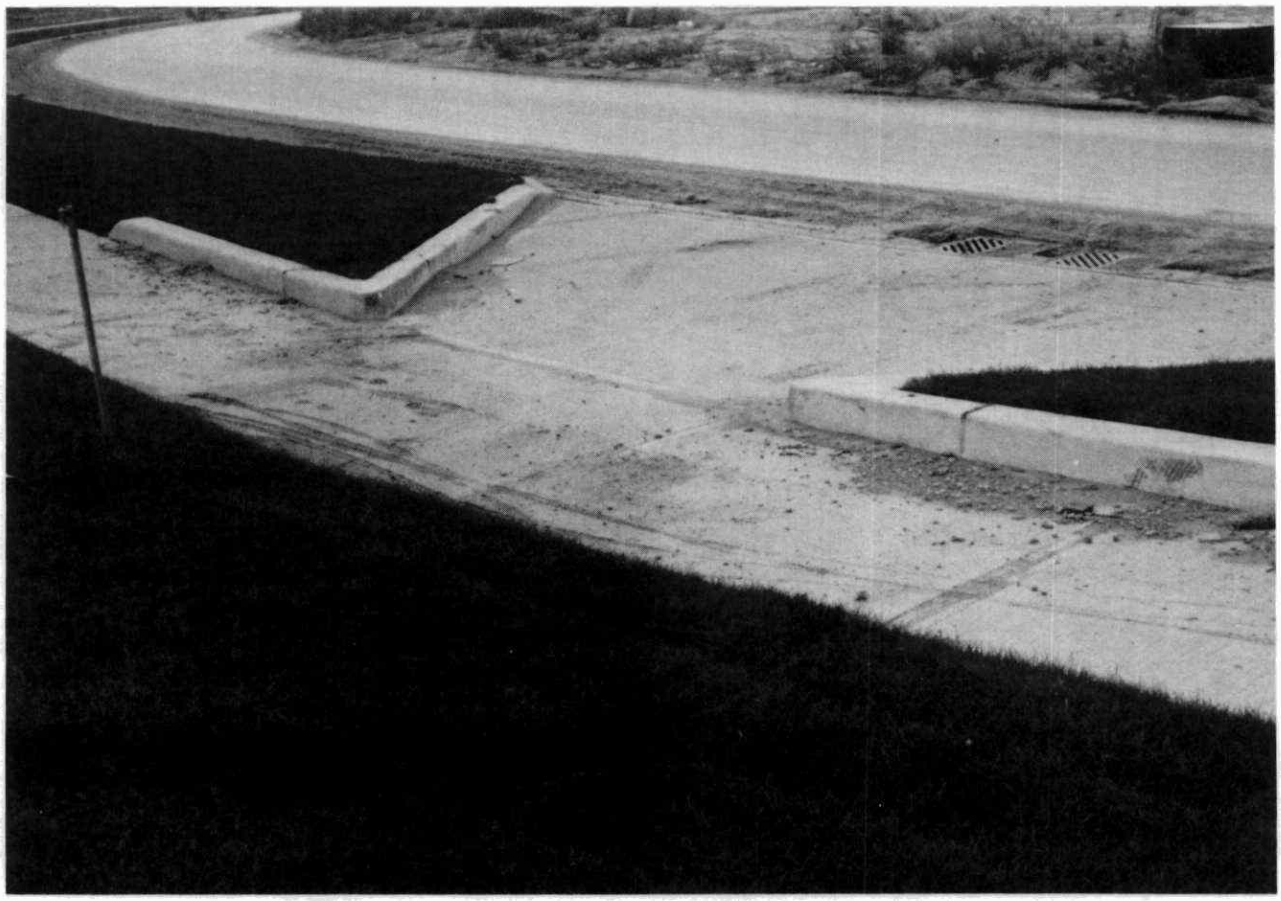


PLATE 12: OVERLAND FLOW INLET
W. RISEBROUGH, MARKHAM

PLATE 13: GENERAL VIEW OF PARKETTE
W. RISEBROUGH, MARKHAM

PLATE 14: GENERAL VIEW OF PARK STORAGE
W. RISEBROUGH, MARKHAM

URBAN DRAINAGE MODELS FOR PLANNING AND DESIGN

By

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A. Charles Rowney

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Proctor & Redfern Limited

Paper Presented to:

The Seminar on Practical Implementation of Storm Water Management Technique

October 20 and 21, 1980

Skyline Hotel
655 Dixon Road
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Introduction

For many drainage design applications, only an estimate of the peak flow rate is necessary for sizing a pipe or other form of conveyance. Most storm sewer systems, culverts, and drains currently in operation were designed in this way, using the Rational Method or one of the other empirical formulae embedded in drainage practice. These systems have, for the most part, performed reliably in situations where the drainage areas were quite small, and where convenience of access was the only objective.

Larger drainage systems, however, brought with them a number of problems which were difficult to address using traditional methods. Storage and routing effects in very large trunk sewer systems can significantly affect peak flows, and could not be directly analyzed with the Rational method. In fact, oversized storm sewer segments are currently being designed specifically for flow attenuation purposes. In combined sewer systems, surcharging and flooding problems are extremely difficult to track down and correct without information on timing, volume, and duration of component hydrographs. In many watersheds, storm sewer outflows represent the bulk of downstream flood flows, increased many times over the natural condition. Mitigative measures may involve storage at several points upstream, and here again more than peak flow estimates are required.

Clearly, a need for more comprehensive analytical and design techniques has developed, and is being met by several drainage "models" which are in widespread use. The term "model" refers to the mathematical representation used to estimate the drainage phenomenon, and strictly speaking even the Rational formula is a model. A more precise image, and more practical one, is to utilize the term Hydrograph models, which most succinctly underlines the important difference. Hydrograph models deal with the volume, timing, duration, and rate of runoff, and this information

is vital to the analysis of larger and more complicated systems.

Hydrograph models are usually computerized because of the number of calculations involved. The most useful ones enable the designer to construct a linked model of the actual pipe or stream system, determine the capabilities of the various links, and automatically perform the routing of sub-catchment hydrographs to the desired outlet. There are a number of benefits attributable to this type of modelling process, aside from the reliability of the flow estimate;

- o Comprehensiveness - by combining the hydrologic and hydraulic functions, the designer is better able to understand the system and identify problems. Peak flows, sewer capacities, and routing effects can all be considered. The results of a hydrograph model analysis may be likened to a moving picture of the system, rather than a photograph.

- o Alternatives - Because of the speed and ease of operation of a working model, the designer can investigate alternative measures far more readily. This is the essence of good drainage planning.

- o Discipline - The use of models imposes a certain discipline of design which makes the final results less subjective. For example, routing would be performed the same way in every case. This enables better comparisons between different analyses of a system, as well as between different reports and projects. Engineering judgement and innovation can then be concentrated upon the results rather than on the detailed techniques of analysis.

For these reasons the authors feel that models have a vital role to play in municipal drainage, in conjunction with traditional methods. The history of modelling in Ontario has been reviewed elsewhere, but an overview is shown on Figure 1. The development and use of models has played a key role in the development of urban drainage technology in the province.

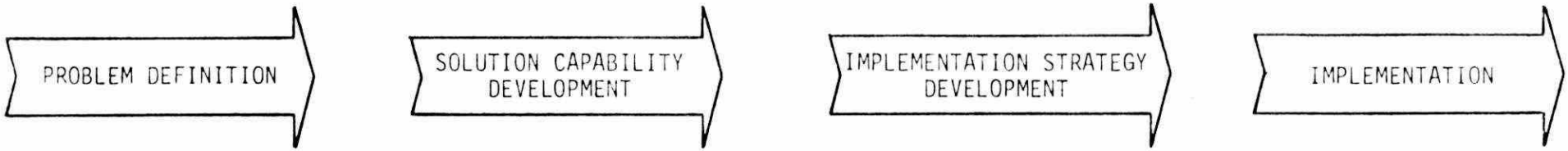
Model Attributes

There are some common attributes of hydrograph models in general, especially the more commonly applied ones discussed in this paper. These often form the basis for selecting a particular one for a project at hand.

A hydrograph model, obviously requires as input a rainfall pattern, (hyetograph) from which the various losses are abstracted. Most models will accept one or more hyetographs to be applied to the subcatchements being modelled. It is possible to simulate the spatial distribution and direction of the storms by varying these hyetographs, but for most small drainage areas this is not necessary.

Representation of infiltration (and often depression storage) is another important aspect of available models which differs from the Rational method. Infiltration is usually depicted as a time variable process which decreases with time. The design of storage facilities is materially influenced by the infiltration rate, and hence the runoff volume.

The surface runoff hydrograph must be computed for each sub-area and used as primary input into the hydraulic routing simulation. Available models use a variety of procedures to achieve this, from simple volumetric runoff per time increment to Kinematric wave theory. Adjustments must sometimes be made to account for pervious/impervious area differences, as in HYMO, for example.



Typical Projects:

- Monitoring
- Great Lakes Loads Evaluation
- Stormwater Bacteriology

Typical Projects:

- Treatment Studies
- Urban Drainage Model Development (CANSWMM, ILLUDAS, etc.)
- Modelling Demonstration Studies (Hamilton, East York)

Typical Projects:

- Domestic and Foreign Practices Review
- Seminars
- Manual of Urban Drainage Practice
- Policies and Guidelines for Municipalities (MOE, Markham, Oakville, MTRCA)

Typical Projects:

- IMPSWMM
- Models Available on Commercial Time-Share Basis
- Stormwater Management Facilities Contructed or under Construction

Markham	Kitchener
Unionville	Waterloo
Scarborough	Newmarket
Vaughan	Oakville

FIGURE 1 - URBAN DRAINAGE PROGRAM

ILLUDAS - (ILLINOIS URBAN DRAINAGE AREA SIMULATOR)

ORIGINATOR: ILLINOIS STATE WATER SURVEY
(TERSTRIEP, M.L. AND STALL J.B.)

BASIS: A close relative to the Rational method, but discretised to permit generation of time-varying flows. Based on a time-area concept of the watershed, with flows at any instant equal to the summation of flows from the total area contributing at that instant.

INPUT FORMAT: Tabular numerical columns. Fixed format.

OUTPUT FORMAT: Tabular columns and headings. Somewhat obscure to interpret at first, but quite quick and useful with experience.

APPLICABILITY: A medium-level model best suited to analysis and design of small urban watersheds. Results may be inadequate in extensive rural or vegetated areas. Can be used either to design or evaluate storage volumes and pipe sizes.

NOTES: Represents paved areas (separate or connected) and grassed areas independantly, which facilitates modelling of many urban drainage alternatives. A good "first cut" tool for urban studies.

Difficult to change its fundamental capabilities, but reprogramming output and peripheral functions is not difficult.

Adequate routing, on the basis of user supplied sewer or channel dimensions is vital if storage, surcharge, or other complex systems are being investigated. The Storm Water Management Model (SWMM) provides the most complete routing, but simpler approaches in other models may be perfectly applicable.

The ability to handle special facilities such as pumps, overflows, diversions and weirs may be important for large combined or sanitary sewer applications.

The hydraulic capabilities of a model may be quite important even when only approximate flow estimates can be made, because a relative assessment of the performance of a system is often useful in design. The design of combined sewer relief overflows, for example, might be based upon locations where flooding first occurs and what maximum surcharge levels can be tolerated, rather than upon a design flow frequency.

Available Models

There are a great variety of models available at present, each with a different set of capabilities. Three which have come to be quite widely used in Ontario are HYMO, ILLUDAS, and SWMM, and these are reviewed in this paper in terms of their applicability to the more practical municipal urban drainage problems. The following pages present a capsule summary of each model.

HYMO - (HYDROLOGIC MODEL)

ORIGINATOR: U.S. DEPARTMENT OF AGRICULTURE
(WILLIAMS J.R. AND HANN R.W.)

BASIS: A unit hydrograph model Generates runoff hydrographs by incremental summation of unit hydrographs. Shape parameters of unit hydrograph derived from empirical functions of watershed height, length, and area.

INPUT FORMAT: Designed as a computer language. Commands are common hydrologic terms. Numerical input is free format and flexible. Highly user-oriented.

OUTPUT FORMAT: Commands are executed and displayed sequentially, so output consists of the original comments and commands interspersed with calculated results. Easy to read and interpret. Debugging may be difficult since print of input data is a direct echo.

APPLICABILITY: HYMO is best suited to medium and large sized rural watersheds, although recently has been adapted for urban areas. Useful for watershed planning studies, or for design of storge facilities such as reservoirs, and for floodplain mapping studies.

NOTES: Can perform computation or storage of hydrographs, and will route hydrographs through a system including junctions, channels and reservoirs. Is very easy to extend or re-program by adding subroutines for any desired operation. Its unit hydrograph basis makes it one of the easier models to apply to widely varied conditions.

SWMM - (STORM WATER MANAGEMENT MODEL)

ORIGINATOR: U.S. ENVIRONMENTAL PROTECTION AGENCY

BASIS: A detailed deterministic model for simulating surface runoff and pipe system hydraulics in urban areas, including surcharging.

INPUT FORMAT: Tabular numerical columns. Fixed format.

OUTPUT FORMAT: Includes summary data and hydrograph printouts as required. Simple to evaluate and intepret, but may be somewhat lengthy.

APPLICABILITY: Best used for generating runoff from urban areas. Is very wide in scope and may be used in detailed evaluations of pipe or channel networks. Can be applied to continuous or event simulations of quantity and quality of runoff, and recent versions include snowmelt computations. Hydraulically the most detailed model.

NOTES: Several versions of SWMM presently exist due to the great deal of interest shown in the model by consultants and governments. The model is not suited to casual re-programming due to its size and complexity, but with some effort it can be modified as required. Is presently not really suited to rural watershed modelling, but can be used successfully in some rural basins with caution.

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The three models considered here are quite different in scope and application. The choice of one of these models over the others will be dictated by the problem to be tackled, the resources of the user, and to some extent the personal preferences of the user.

MODEL SELECTION

The models described above are applicable to a wide range of conditions, and they form a fairly complete package for urban drainage planning and design. Since all the models are widely available, choice of which one to use will depend on the circumstances.

As a general rule, the simplest model which produces the required information should be applied. There is no point in using a detailed model if detailed results are not required, or if adequate data is not available. For example if the drainage basin is small, and if only peak flows are required, the Rational method will suffice. If the analysis of surcharge or other more complicated details is required, SWMM should be considered.

The model should fit the basin to be analyzed. In large areas, particularly rural watersheds, HYMO is used. In smaller or urban areas, ILLUDAS or SWMM can be used, although current investigation shows HYMO can be applied in urban areas if proper adjustments are made to the parameters K, Tp and CN.

The ILLUDAS model is primarily useful for the design of piped systems and simple storage applications. It requires less time to set up and run than SWMM, and carries out a good analysis with relatively simple routing.

SWMM is best suited to the analysis of the more complex pipe systems, although it also has very good open channel routing. Its hydrologic component, the Runoff Block may be used by itself for small areas. Also the routing component, the Transport Block, may

be applied by itself using runoff results from other models.

Finally, the requirements for computer capacity are important, as many offices computers have limited core space. The only program considered here which is too large for small machines is SWMM. Where out-of-house computers are used, space is not a problem, but costs become significant. In this situation, it is usually found that SWMM is slightly more expensive than ILLUDAS or HYMO, which are about equal in cost. In a strictly hand-calculator environment, the Rational method and various hydrograph approximation techniques may be the only option.

Typical Applications

The following examples of commonly encountered urban drainage problems illustrate how the above models might be applied in practice.

Master Drainage Plans

Master Drainage Plans are commonly carried out on a watershed basis, and basically involve defining major system drainage, and determining the required level of stormwater control. Precise location or sizing of structures may not be required, but analysis at this level must be accurate enough to mesh with analyses in more detailed subsequent design, and to provide guidance in overall watershed development.

It is possible to use HYMO for pre-developed conditions and SWMM for post-developed, but simplicity and economy suggest the use of one model for the whole study, if possible. HYMO is reasonable for urban modeling if adjustments are made to the curve number, and to the unit hydrograph shape parameters (IMPSWM, 1979), so HYMO has been used for hydrologic analyses for several current Master plans.

Experience has shown that the model, when applied with care, is quite adequate for this type of study. The structure of the model lends itself to rapid evaluation of alternative drainage schemes, and the computational routines are adequate for evaluating common storage and routing structures. While the peak flows so generated may be different from those determined at a more detailed level, the relative changes in flow due to urbanization are reasonable. For this reason, the placement and sizing of control volumes is usually finalized in subsequent detailed studies.

Subdivision Design

More information about land use is usually available, and detailed pipe layouts are required. Depending on the scale of the development and on previous planning studies, several alternatives may present themselves.

If the subdivision is small, and control devices are centralized somewhere downstream, it may be sufficient to apply Rational method calculations, and concentrate on drainage at a local "convenience" level. However, planning for major system drainage should not be neglected.

If control volumes are sited so that runoff hydrographs from the subdivision are required, or if on-site measures such as roof top disconnection are proposed, then more detailed modeling is indicated. ILLUDAS may be quite adequate, and it is very convenient for estimating storage volumes or for assessing such things as impervious area separation.

When further studies will require detailed assessment of hydraulics, SWMM is probably indicated. This is primarily because the results of the Runoff block computations can be quickly and easily manipulated through use of the Transport block.

Design of Storage Volumes

For storage design, especially at a large scale level, HYMO is usually quite sufficient to allow an assessment of storage and outflow relationships. However, if local swale storage or other diffuse control measures are indicated, ILLUDAS or SWMM are preferable. There is no doubt that when "super pipes" or other detailed designs are attempted SWMM is much more powerful than either ILLUDAS or HYMO.

A typical example of storage volume design has been taken from a current project to compare how SWMM and HYMO might each be used to evaluate control volumes required in an urbanizing basin. HYMO was first used with rural parameters coded. Urban conditions were then approximated by halving the values for the rural K and Tp and by increasing the curve number. These changes reflect the increased imperviousness and decreased response time of urban basins.

SWMM was applied to represent urban runoff, and then parameters were adjusted to reflect rural conditions. Imperviousness was lowered and infiltration rates were changed.

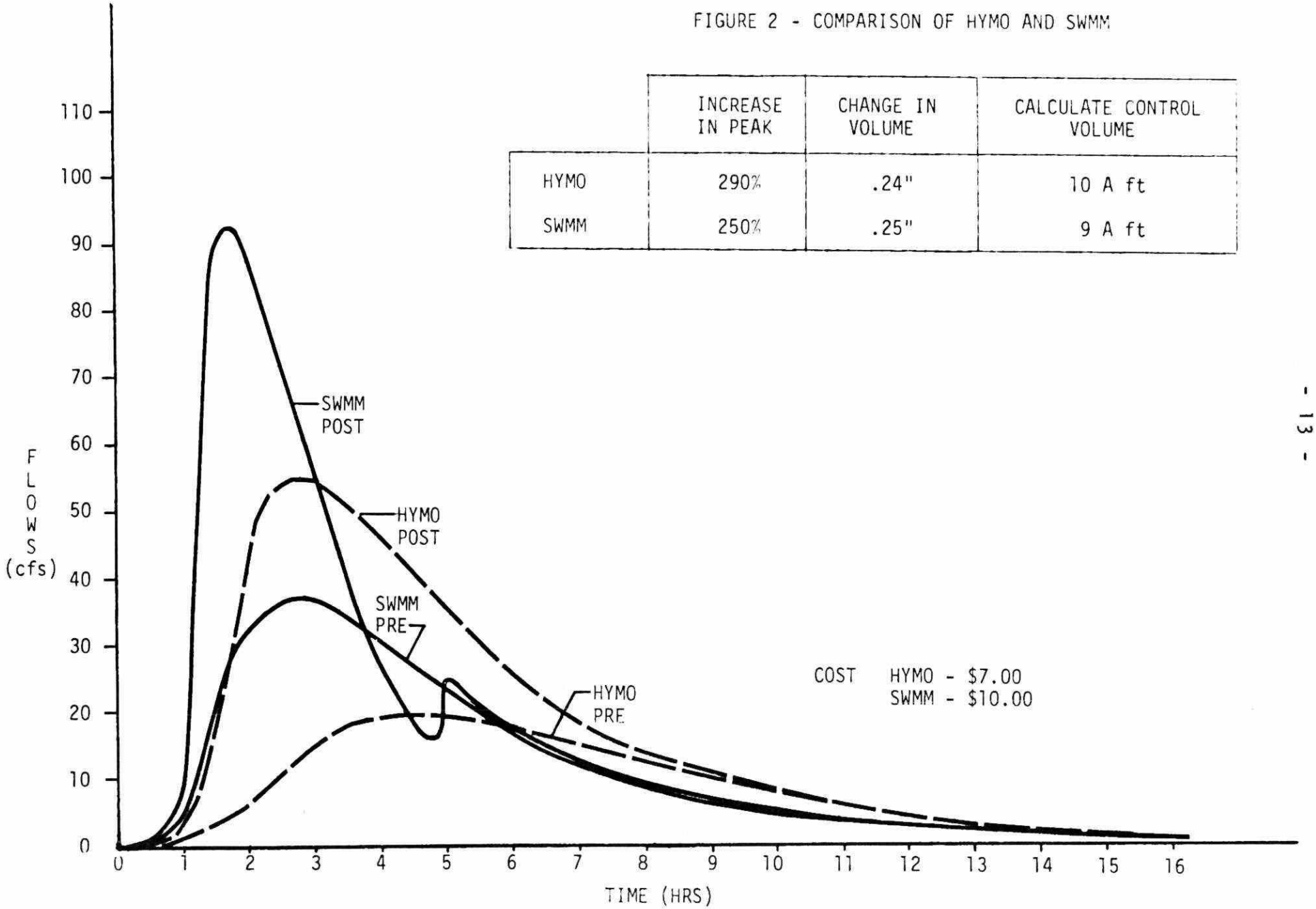
As shown in Figure 2, the results of the two approaches are in good agreement, for the purposes of the study. The change in runoff volume due to urbanization is in close agreement, as is the change in the relative magnitude of peak flows. What is most interesting is that the required control volumes calculated for either model are as close as is required in a planning study. Computer costs were somewhat higher for SWMM, and HYMO required slightly less set-up time.

Some Recent Applications

Model usage is now well established in drainage practice and many examples of their application have been reported. The following

FIGURE 2 - COMPARISON OF HYMO AND SWMM

	INCREASE IN PEAK	CHANGE IN VOLUME	CALCULATE CONTROL VOLUME
HYMO	290%	.24"	10 A ft
SWMM	250%	.25"	9 A ft



are some recent projects, conducted by the authors, in which one or more of the models were applied:

St. Catharines - SWMM was used to analyze combined sewer flooding and relief requirements for the St. Patrick's Ward and the Sap Ditch drainage areas.

London - HYMO is being applied to evaluate potential drainage problems and stormwater control requirements in Dingman Creek. SWMM is being applied for specific urban sub-areas.

Saulte Ste. Marie - SWMM was used to investigate flooding and relief alternatives in a heavily infiltrated sanitary sewer. Hydrographs were developed and calibrated to measurements, and used in the EXTRAN block to determine surcharge levels.

Scarborough - ILLUDAS was employed to evaluate overland flow routes for a new subdivision, and to determine storage requirements to meet municipal criteria.

Toronto International Airport - HYMO was employed to determine pre- and post-development flows from the airport property, including substantial areas of pavement. Typical area were checked with SWMM modelling.

Edmonton - SWMM was employed to design several interconnected lake systems including maximum and minimum storage volumes, pipe systems, and overflow routes.

Winnipeg - SWMM was used to design the size, volume, and location of a storage pipe for sanitary sewer relief.

Saint John - SWMM was used to analyze a downtown drainage system, including the dual drainage system, to determine requirements for urban renewal.

Ajax - HYMO was employed to determine storage volumes and major system capacities for a master drainage plan.

EROSION CONTROL PRACTICES OF THE MINISTRY OF TRANSPORTATION AND COMMUNICATIONS

BY

J. J. ARMSTRONG

HEAD

ENVIRONMENTAL TECHNICAL DEVELOPMENT SECTION

MINISTRY OF TRANSPORTATION AND COMMUNICATIONS

Presented to: Storm Water Management Seminar
Skyline Hotel
October 20-21, 1980
Toronto, Ontario

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EROSION CONTROL PRACTICES OF THE MINISTRY OF TRANSPORTATION AND COMMUNICATIONS

1. Introduction

The construction of a modern highway involves a drastic changing of the land over which it traverses. Such construction results in the reduction of small hills and knolls, the material from which is placed in depressions and stream valleys in order that the gradient will be as flat as economically possible and consistent with the type of traffic anticipated to use the facility. At the same time, large areas of land are rendered impervious to water infiltration from the application of asphalt or concrete pavement. This results in higher than normal runoff with a consequent increase in the risk and occurence of erosion and sedimentation problems.

When highway construction was on much smaller scale, as during the period generally up to the 1940s in Ontario, there probably was not as high a risk of erosion and sedimentation inputs as would occur with the construction of a highway today.

Not only are modern highways conducive to the generation of high erosion, the impacts are considered more important due to the increasing intensity of land uses, the scarcity of environmental features impacted by erosion and associated sedimentation and a much higher level of concern for the loss of environmental quality resulting from erosion and sedimentation. At the same time, such erosion and sedimentation has its own contribution to high construction costs. Rills and gulleys created by water flowages down slopes and ditches must be filled in; accumulated sediment in culverts must be removed; compensation for the death of trees whose roots have been smothered by sediment has to be paid. In addition, other costs, not borne by the construction contractor or the Ministry are paid, often unknowingly, by the general population in terms of reduced fishing opportunities, degraded swimming areas, increased populations of biting flies, etc. i.e. a reduced human habitat quality.

Over the years, the Ministry of Transportation and Communications has been making positive efforts to reduce the amount of erosion and sedimentation associated with its projects. Progress has been slow as various techniques are tried, evaluated, discarded, modified, etc., in an attempt to find the most appropriate and cost-effective approaches and techniques.

In the early years, erosion and sedimentation control measures were placed in the contract for highway works solely on the basis of protecting the work and/or reducing costs associated with erosion and sedimentation. Over the years, however, this attitude has been changing to the extent that some of the "old timers" are often, and increasingly so, perturbed about the inclusion of measures that "would never be permitted in my time!".

The purpose of this paper is to provide a description of some approaches currently being developed and used within M.T.C. in an attempt to develop an erosion and sedimentation control program for the Ministry.

2. Erosion and Sedimentation - Some Basics

2.1 Magnitude and Extent

The detachment, transport and eventual deposition of soil particles as a result of the forces of water and wind is a natural process that has shaped the topography and soil characteristics of land surface and sub-surface features. The exposure of mesas in the American Midwest, the rounding and smoothing of precambrian granites in the Laurentian Shield, the channelization of the Niagara Gorge and the formation of the Niagara Escarpment attest to the magnitude of the effects of natural erosion. Locally, the vast amounts of material deposited in the major moraines of Southern Ontario and the layering of fine-grained sediments observable in the exposed faces of the Niagara Escarpment, attest to the magnitude of the process of sedimentation over time.

The effects of such processes are seldom of great consequence where natural counteracting factors such as vegetation are operative. Vegetation not only assist to bind soil particles, but also helps to prevent their dislodgement through the energy absorption of leaves and stems which prevent the direct impact of water droplets onto soil particles.

Of great consequence, however, is the accelerated erosion and sedimentation which occurs as a result of Man's development activities which expose soil surfaces and facilitates erosion. Such erosion is characterized by high rates of soil movement over a short time frame. On an annual basis, the amount of soil moved by the forces of water can be staggering. For example, the estimated annual silt discharge of the Mississippi River at its mouth is approximately 730 million tons (1) or an amount of silt which would cover 283,000 acres one foot deep. Taking P.L.U.A.R.G (2) results for Southern Ontario, the total contribution of Canadian agricultural land to streams in the Great Lakes basin in 1976 was 1,200,000 tons and 465 acre-feet.

According to a recent E.P.A. report (3), fifty percent of sediment deposition is attributable to agricultural sources, but the highest rates of soil erosion are attributed to construction and active surface mining.

Table 1, derived from (3) illustrates this point rather clearly.

TABLE 1

The Relative Soil Loss due to Erosion from Various Land Uses.

Land Use	Tons per mi^2 per year
Forest	24
Grassland	240
Cropland	4,800
Harvested Forest	12,000
Active Surface Mines	48,000
Construction	48,000

Values greater than those reported in Table I were reported by Wolman (4) for various construction projects in Maryland. Table 2 demonstrates some of these values.

TABLE II

Annual rate of sediment yield from construction activities in Maryland (from Wolman [4])

Construction Activity	Tons per mi^2 per year
Industrial Park	72,000
Construction Site	140,000
Housing Subdivision	121,000
Housing Subdivision	25,000
Housing	5,600
Housing (probably a low estimate)	11,300

Table II also shows that a wide variation can exist and that high rates of sediment yield do not accompany every construction project. The reason for this varibility is due to the influences of the various factors affecting the rate of sediment yield such as slope, gradient, slope length, soil erodibility, rainfall intensity and duration as well as the degree and type of soil erosion control established.

2.2 Sedimentation

When particles have been dislodged by the forces of erosion and transported by water, settlement can only occur when the forces acting on the particle become less than the forces of gravity. Sediment can, therefore, be transported for long distances by high flows, especially if the size of particle is small. Since the specific gravity of transported mineral soils is generally greater than that of water, the particle will eventually settle out as the water velocity decreases. Small particles (eg. colloidal clays) may remain in suspension for very long periods after the water velocity has been reduced to imperceptible levels as in a sediment trap. The resulting turbidity is an indication that greater upward forces are acting on the individual particles than the force of gravity.

2.3 Impacts Due to Erosion and Sedimentation

The three phases in the process of erosion and sedimentation are detachment, transport and deposition. At each of these phases certain condition changes occur and may result in effects, both negative (impacts) and positive (benefits) of primary, secondary, tertiary etc. levels. These condition changes and effects may affect biotic, abiotic or social-economic categories or combinations thereof. Table 3 shows the condition changes, primary, secondary, tertiary effects for each of the three phases.

Table III

Condition changes with primary, secondary and tertiary effects associated with the Erosion & Sedimentation process.

PHASE	CONDITION CHANGES	1° EFFECT	2° EFFECT	3° EFFECT
Detachment	(a) Soil particles free to move after detachment by falling rain.	- Soil particles begin to move.	—	—
	(b) Soil particles free to move after detachment by flowing water.	- Soil particles begin to move.	—	—
Transport	(a) Soil particles in suspension in water.	- Increase in turbidity.	- Increase in difficulty in treating water for domestic supplies.	- Increased cost to users.
			- decrease in water quality for fish life.	- Lowered fish production.
			- Aesthetic deterioration	- Increased abuse of water quality
		- Release of heavy metals, toxic chemicals.	- Increase in heavy metal concentrations in food chain	- Potential long term effects on man.
			- Increase in toxic chemicals in food chain.	- Potential long term effects on man.
	(b) Soil particles "bump" along bottom of channel	- Soil particles assist in dislodging additional soil particles from channel	- Channel becomes longer	- damage to the land base of production.

Table III page 2

PHASE	CONDITION CHANGES	1° EFFECT	2° EFFECT	3° EFFECT
Deposition	(a) Deposition in streams, lakes etc.	- Damage to fish habitat (pools, spawning areas, etc.)	- Reduction in fish populations.	- Reduction in man's potential use.
		- Creation of substrates preferred by certain biting flies (Tabanids and Mosquitoes)	- Increased annoyance.	- Possible loss of land values.
			- Increase in potential for disease transmission.	- Human & economic losses.
		- Change in habitat for certain aquatic organisms.	- Reduction in fish food abundance desired for certain species	- Reduction in certain fish species.
			- Increase in populations of species used as food for certain fish.	- Increase in populations of other fish species.
	(b) Deposition over roots of vegetation (woodlots etc.)	- Suffocation of roots.	- Death or damage to vegetation	- Change in ecological succession
	(c) Deposition in pipes, ditches etc.	- Additional removal costs.	- Potential damage to installations	- Overall decrease in economic efficiency.

Although fantastic amounts of material have been eroded and subsequently deposited over geological history, the rates of sediment yield have seldom been high. Consequently, the various floral and faunal components of natural ecosystems are generally intolerant of high sediment concentrations. The reason for such intolerance is associated with the relative stability with which most species have been subjected during their evolution. Some species, however, are very tolerant to sediment concentration and play a very important role in promoting soil stability especially where erosion and sedimentation processes are active such as river banks and beach dunes.

Even with effects of soil erosion and sedimentation presented, one may still be inclined to adopt a casual attitude, reasoning that the value of the product of construction expressed as a need of society exceeds the tangible and intangible values of the environment affected by erosion and sedimentation. This is especially true if one does not appreciate the fragility of the links with which each component of the ecosystem are connected, or that Man's future well-being depends on the integrity of such ecosystems. Accelerated erosion and consequent accelerated sedimentation can disrupt such ecosystems.

2.4 Types of Erosion

Erosion is the detachment and transport of soil particles by water, wind, ice or gravity. In terms of water-caused erosion, which will be the main consideration of this paper, erosion can take four forms:

- sheet erosion
- rill erosion
- gully erosion
- stream and channel erosion and transport

Sheet erosion is the detachment of soil particles uniformly over an area so that the loss of soil may be almost imperceptible. Generally, sheet erosion occurs on very gradual slopes where water velocities are low. On steeper slopes, sheet erosion rapidly takes the form of rill erosion in which small rivulets are formed by the concentrated flow down the slope. Where soils are especially erodible on moderate slopes, such rill erosion can rapidly create gullies, especially on the lower sections on such slopes. Whereas sheet erosion removes soil uniformly by low volume and velocity flows, rill erosion removes soil from channels through the action of low-volume concentrated flows of moderate velocity. Gully erosion is created by high volume concentrated flows of high velocity.

The erosion that takes place in streams and channels is caused by high volume and velocity concentrated flows. The scouring of streambanks and the consequent formation of pools and riffles takes place as the stream responds to the tendency to follow the mathematical expression for a "sine-generated curve" because this is the type of curve involving the least work in turning (5).

2.5 Principles of Erosion and Sedimentation Control

From the previous discussion, three principles of erosion and sedimentation control can be identified.

2.5.1 Minimize Soil Exposure

Soil exposure to rainfall or running water will be detached and transported because of the transfer of energy from the erosive force to the soil particles. This process will continue at a rate dependent on the interplay of the factors identified in the Universal Soil Loss Equation.(6) Under given conditions of soil erodibility, rainfall, slope gradient and length, the removal of vegetation to expose soil will increase

the value of the VM factor. Thus, the most obvious way to minimize the amount of soil erosion is to maintain the VM factor at as low a value as possible. Often, the only way to accomplish this objective is to minimize the area of exposure to that minimum amount needed for site development. However, this may not be sufficient if the soils are very erodible. Thus, the retention of vegetation on highly erodible sites for as long as possible will minimize the amount of erosion.

Where erosion potential is high and it is impossible to further minimize the potential amount of erosion by minimizing the size of the area needed for site development, consideration should be given to the minimization of the time interval and the time period of soil exposure. For example, where the installation of services has been accomplished and the serviced lost are awaiting purchase and/or erection of buildings, the application of soil erosion control techniques on a temporary basis will again reduce the VM factor so that the erosion potential will not be realized. The various techniques that could be used include the application of seed and mulch, mulch alone, chemical soil stabilizers or mechanical means such as plastic sheets. It should be pointed out that the selection of the measure to be used will depend on such factors as costs, effectiveness, time of protection and weather conditions.

It is also well known that the time of the year during which soil is exposed will influence the amount of erosion.

2.5.2 Make Water Walk, Not Run

The erosive force of running water is well known; as water is allowed to concentrate, its erosive potential increased considerably. Likewise, the reduction in velocity not only reduces the potential erosive power, but also allows suspended sediment to settle.

Many of the soil erosion control measures utilize this principle. The application of sod or seed and mulch will retard the concentration of water by acting as an energy attenuator to force water to walk rather than run. The use of rip-rap in ditches accomplishes the same objective. It should be noted that the various techniques for slowing down the velocity of water have to be used where they will be able to counter the forces of such running water. Thus the use of sod in a steep ditch will only result in the loss or damage of the sod without reducing the amount of erosion.

2.5.3 Retain Sediment on the Site

Even with the application of the previous two principles, some sediment will be produced. The retention of such sediment on the site will greatly reduce the potential damage to environmental features. Sediment can be retained by two methods: filtering run-off as it flows and detaining sediment laden run-off for a period of time, so that the soil particles settle out. This may be accomplished by the construction of sedimentation traps at strategic locations in drainageways or by the construction of sediment basis through which water is diverted. Frequently the approach that is used to prevent environmental damage is to construct sediment basins or traps in order to directly attack what is perceived to be the main problem - the sediment. Rather, the use of sediment retention methods should be considered as a back-up protective measure to the application of erosion control methods employed further up the drainageway. The best way to control sediment is to control erosion.

3.0 Erosion and Sedimentation Control in Project Development

Consistent with the approach that planning deals with a subject from the general to the specific, the consideration of erosion and sedimentation should proceed from the broad area basis to the specific location throughout project development.

Ideally, these considerations should proceed from the broad area considerations, sub-province, county, regional municipality, etc. down to the individual slope, ditch, etc. The objective is, at the broad level, to minimize erosion and sedimentation through avoidance first and, where a potential impact is considered unavoidable under such circumstances, then mitigation must be applied. "Avoidance" planning is applied throughout four stages described below; "mitigation" can, for obvious reasons only be applied at the design and construction levels. The four stages of project development are presented below along with a description of the general approach used at each stage.

3.1 Network (Area) Planning

At this stage an emphasis is placed on gathering and mapping information on features that would either be affected by erosion and/or sedimentation or which would contribute to it. Because eroded materials tend to settle out in watercourses, thus creating a condition change and associated stream ecosystem effects, the location of streams and more particularly, streams sensitive to the effects of sedimentation are mapped. Streams which are most affected by sedimentation are those containing trout species while streams which are progressively affected to a lesser degree are those containing game fish such as smallmouth bass, pickerel, etc. Those streams affected least are those which contain only coarse fish such as carp, mudcat, gar pike, etc. Generally such species can withstand high sediment deposition.

Other features which could be mapped are those which relate to the protection of man-made structures such as water impoundments which could be reduced in efficiency through the contribution of sediment from highway works. As a general rule of thumb, impoundments occurring within two miles downstream of new highway construction or reconstruction on a medium sized stream can be expected to be

adversely affected. In terms of features of the landscape which would contribute to erosion and sedimentation problems, such features as topography and soil types or soil associations would be suitable for mapping.

Alternative corridors within the area are evaluated on the basis of not only the traditional traffic considerations, but also in terms of the effects on environmental factors including erosion and sedimentation. The objective would be to maximize the potential returns from the highway while at the same time minimizing the adverse environmental effects. This approach theoretically minimizes environmental (and often engineering) problems at later project development stages.

3.2 Route (location or functional) Planning

At this stage of project development, the goal would be find a route location that provides the best returns in terms of cost, traffic service and minimization of environmental impacts. The corridor within which the new facility will pass is generally from three to ten miles in length and generally two to three miles in width. Within such an area a number of alternative routes will be identified and evaluated against a number of engineering, cost and environmental factors. In terms of erosion and sedimentation control, the objective would be very similar to that at the Systems level and the indicators identified (trout streams, water impoundments, etc.) would generally be the same but would be mapped at a much more detailed level. Likewise, the evaluation would also be much more detailed.

Again, the overall objective would be to minimize the degree of condition changes and, therefore, impacts associated with erosion and sedimentation through avoidance considering all the trade-offs which are involved.

3.3 Design

This stage is usually divided into two phases, preliminary and detail design. In preliminary design, the route (or type of work in cases of reconstruction) is examined in order to confirm the need and justification. Preliminary horizontal and vertical alignments are generated and evaluated in terms of engineering acceptability, cost and environmental impact and implications.

In terms of potential erosion and sedimentation impacts, data are collected at this stage on the degree of sensitivity of the streams on the project to sedimentation. Where a particularly sensitive stream is identified, the alignment alternatives may be examined with the objective of minimizing the erosion potential of the work and thus reduce the potential impacts on the watercourse.

In the next phase,detail design, the contract drawings are completed and the contract package is put together. It is at this phase where the fine design details are clearly defined in the contract drawings and the wording of special provisions is clearly written. In terms of erosion and sedimentation control, the contract drawings would identify the locations where special erosion and/or sedimentation control measures were to be taken. They might also indicate the sequence in which the work in a particular area was to be conducted in order to reduce erosion and sedimentation problems. The special provisions, being part of the specifications for the work, would define for contract management purposes, the specific requirements of the contractor. For example, a special provision which is commonly placed in contracts directs the contractor not to work in or near a specified stream during a specified time period in order to reduce the contribution of sediment to the stream during a critical time period. Or a special provision may tell a contractor when a sedimentation trap or basin was to be cleaned of sediment and may specify the manner in which it was to be removed.

3.4 Construction

Given the strict requirements of the contract documents, one might be inclined to assume that any erosion and sedimentation problems would be only as good as the design or damages would only occur as a result of unusual weather conditions such as an exceptionally heavy rainstorm. Such, however, is not the case, since a great deal of damage (or a reduction of such damage) can be done by practically anyone on the job. For example, the placement of an effluent hose from an unwatering operation on level ground where the force of the water could create a great deal of erosion damage could be prevented if the effluent hose were directed to a sedimentation basin or even onto a hard surface. Often, opportunities arise on a job to reduce environmental damage due to erosion as, for example, on one job where a bulldozer operator placed a load of earth to redirect a flow of water which was discharging down an embankment causing a great deal of erosion.

In MTC many of our project supervisors and inspectors have been exposed to an environmental awareness course which attempts to provide information on how field personnel can minimize environmental damage on the job.

4.0 The Determination of Watercourse Sensitivity to Erosion and Sedimentation

In 1980 the MTC issued a guideline entitled "Guidelines for Analyzing Surface Water Sensitivity to Erosion and Sedimentation" in which was presented a technique for the utilization of a great deal of readily available information to determine the degree of sensitivity of a watercourse to erosion and sedimentation. Knowing the degree of sensitivity of a watercourse, a planner or designer would be in a better position to identify and select erosion control techniques and approaches in a cost-effective manner. At the same time, he would be in a position of not including special erosion and sedimentation control measures on streams which were not especially sensitive.

The guidelines have been prepared on the basis that the following three factors affect the degree of sensitivity to erosion and sedimentation:

(a) The Sediment Yield Rating Factor

(b) The Inability of Surface Water to Absorb Sediment

(c) The Sensitivity Attributes of the Watercourse.

4.1 - The Sediment Yield Rating Factor

The sediment yield rating factor is determined using five subfactors:

(i) Runoff

(ii) Soil Erodibility

(iii) Exposed slope length and slope gradient

(iv) Area of land exposed

(v) Location of the watercourse.

4.1.1 - Runoff

Since the influence of runoff is greater during the spring than at any other time of the year, this sub-factor is given a high rating when soils of a construction site are to be left exposed during this time of year. Medium ratings are given if soils are to be exposed from 2-8 months which do not occur in the spring period. And lastly, a low rating is given if soils are not to be left exposed for longer than 2 months.

4.1.2 - Soil Erodibility

Wischmeir et al (7) developed a nomograph for use in the Universal Soil Loss Equation which determines K an erodibility factor. This sub-factor is assigned a high rating if K factors determined for the soils of the site are greater than 0.40, a medium rating if the K factor is between 0.2 and 0.4 and a low rating is assigned for any values lower than 0.2.

4.1.3 - Exposed Slope Length and Slope Gradient

The length-slope sub-factor (LS factor) was also developed for use in the Universal Soil Loss equation and represents the contribution to the potential for erosion from slopes attributable to the length and gradient. Foster and Wischmeir (8) developed an equation and subsequently a nomograph from which the LS factor is calculated knowing slope-length in feet and the slope gradient in percent.

Subjectively, it was determined that an LS value of greater than 5 would be classified high, 1-5 as medium and less than 1 would be low.

4.1.4 - Area of Land Exposed

In determining criteria for classifying construction site area, subjective determination is again employed. An exposed area of greater than 1.5 ha would be classified as high, 0.5 to 1.5 ha as medium and less tha 0.5 as low.

4.1.5 - Location of the Watercourse

A high rating for this component is assigned in those cases where construction work would be in or very close to the watercourse. A medium rating would be assigned where the work was further removed from the watercourse and there were drainage connections with the watercourse. A low rating would be assigned where the distance of the work from the watercourse was long and the contribution of sediment to the watercourse was therefore deemed to be low.

4.2 - Inability of Surface Water to Absorb Sediment

The factor "Inability of Surface Water to Absorb Sediment" reflects the degree of damage to environmental components from the watercourse's inability to transport contributed sediment and thus reduce the degree of impact. Since larger watercourses

have the ability to so "dilute" the environmental effects they are given a low rating while other watercourses, having smaller flows are given medium ratings. High ratings are assigned to very small streams which are also tributary streams many of which have high environmental sensitivities.

Since the size of lakes and ponds also affects its ability to absorb sediment, small lakes are assigned a high rating for this factor, while large lakes are assigned a low rating. Table IV provides the appropriate criteria.

4.3 Watercourse Sensitivity

The following components affect the contribution of this factor to the overall watercourse sensitivity rating:

(a) Aquatic Ecosystems
(b) Recreation uses and potential
(c) Water Consumption
(d) Water Engineering Facilities

4.3.1. - Aquatic Ecosystems

For the purpose of the guidelines, three types of aquatic ecosystems are defined as follows:

Rivers - including brooks, creeks, streams and rivers
Lakes - including ponds, lakes, reservoirs
Wetlands - including swamps, meadows, marshes, etc.

Within each of these broadly defined ecosystems, the differing aquatic organisms will determine the sensitivity of the unit. In the case of rivers, the presence of trout or endangered species of life is the criterium for assigning a high rating. A medium rating is assigned to a river which contains species such as - walleye, perch, etc.

TABLE IV

STEP 3 - INABILITY OF SURFACE WATER TO ABSORB SEDIMENT

	HIGH	MEDIUM	LOW
Physical Nature of Surface Waters	Wetlands, Ponds, (< 1 ha) Streams, Creeks, (1-99 c.f.s ·03-2·8 m^3/s) Intermittent Streams	Streams Minor Rivers (100-1000 c.f.s. 2·8 to 28·0 m^3/s) Reservoirs Lakes (1-99 ha)	Lakes (> 99 ha) Major Rivers (> 1000 c.f.s) (> 28·0 m^3/s)

Flows of rivers and streams to be Mean Annual flow

Sources: 1) Watercourses - Historical Streamflow Summary — Water Survey of Canada (Environment Canada)

Note: If recording station is determined to be distant from area of concern (reference map with above publication) flowrates can be determined proportionately based on drainage area.

If no data available for stream of concern flowrates can again be estimated using flowrates from an area stream and proportionate drainage areas.

2) Lakes – Area Maps, Air Photos, etc.

Watercourses containing carp, bullhead, etc. are assigned a low rating. Other criteria for rating aquatic ecosystems are provided in Table V.

4.3.2 - Recreation Uses and Potential

Four major sub-categories of recreation were determined that could be affected by sediment - swimming, boating, fishing and viewing (aesthetics).

Information obtained from the Canada Land Inventory and the Ontario Land Inventory is used to determine the appropriate rating based on the assumption that areas with higher capability ratings have greater sensitivity to erosion and sedimentation impacts.

4.3.3 - Water Consumption

The ratings for this sub-factor are defined on the basis of the water consumption uses to which a potentially affected water-course is subject and the type of water treatment employed, i.e. the degree to which water quality could be reduced by sediment. The appropriate criteria for this sub-factor are found in Table V.

4.3.4 - Water Engineering Facilities

Water engineering facilities include dams, reservoirs, drainage diversion channels, canals and harbours. Generally, effects of sedimentation decrease with distance of such facilities downstream. In determining the ratings, the criteria for this sub-factor are given in Table V.

TABLE V
STEP 4 - SENSITIVITY RATINGS

Factor	High	Medium	Low	Sources
1. Aquatic Ecosystems				
A. Streams	Trout Streams, or Potential Trout str. Rare or Endangered Species (Fish or Plant)	Warm Water Game Fish Streams - walleye, yellow perch, small mouth bass, sauger.	Coarse Fish Streams - carp, bullhead, white sucker.	1. District Biologist, M.N.R. 2. Fisheries Branch, M.N.R. 3. Canada and Ontario Land Inventory Maps for Recreation. 4. National Museum and R.O.M. for endangered fish species. 5. Provincial Parks Branch, M.N.R. for important plant species and communities.
B. Lakes	Oligotrophic Lakes - deep, little vegetation, large, cold lower layer. Rare or Endangered Species (Plants or Animals)	Mesotrophic Lakes - shallow, abundant vegetation, little cold water.	Eutrophic Lakes - little vegetation, low quality fish, almost 'dead'.	
C. Wetlands	High Value Wetland Wildlife. 1 - 2 W (Source 3) High value as a Nutrient Filter. Rare or Endangered Species (Plants or Animals)	Medium Value Wetland Wildlife 3 - 5 W (Source 3) Medium Value as a Nutrient Filter. (Water flows mainly in a channel)	Low Value Wetland Wildlife 6 - 7 W (Source 3) Low Value as Nutrient Filter. (Not significant flow directly through)	
2. Recreation *				
A. Swimming	High Quality 1 - 3 B (Source 1)	Medium Quality 4 - 5 B (Source 1)	Low Quality 6 - 7 B (Source 1)	1. Canada and Ontario Land Inventory Maps for Recreation. 2. Conservation Authorities Branch, M.N.R 3. Regional Park Planners, M.N.R. 4. Outdoor Recreation Group, M.N.R. 5. District Office, M.N.R.
B. Fishing	High Quality 1 - 3 A (Source 1)	Medium Quality 4 - 5 A (Source 1)	Low Quality 6 - 7 A (Source 1)	
C. Boating	High Quality 1 - 3 C, U, Y, (Source 1)	Medium Quality 4 - 5 C, U, Y, (Source 1)	Low Quality 6 - 7 C, U, Y, (Source 1)	
D. Aesthetics	High Quality 1 - 3 F, V, (Source 1)	Medium Quality 4 - 5 F, V, (Source 1)	Low Quality 6 - 7 F, V, (Source 1)	
* Opinions of listed Sources should also be considered If subjectively of high regional importance (though not by C.L.I.) it should be considered as high.				
3. Consumption	No treatment of Consumed Water or treatment insufficient to handle increased turbidity levels (Type I Facility)	Treatment facilities able to handle moderately increased turbidity levels (Type II Facility)	water not used for consumption or treatment facilities able to handle high turbidity levels. (Type III Facility)	1. Min. of the Environment Environmental Assessment and Planning Division. 2. Industrial Directories. 3. Agricultural Reps., Min. of Agriculture and Food
4 Water Engineering Facilities. (Dams, Reservoirs, Channels, Canals, Harbours)	Near Construction Site downstream (less than 2 miles)	Distant from Construction Site downstream (> 2 miles) Ability to settle suspended sediment or concern re suspended sediment damage.	None Downstream or no concern of settling of suspended sediment.	1. District Offices - M.N.R. 2. Eng. Services Br. - M.N.R. 3. Conservation Authorities. 4. Harbour Commissions (re Commercial Harbours) 5. Small Craft Harbour Br. (Fed. Dept. of Transport)

4.4 - Use of the Total Potential Impact Worksheet

Figure I, the Total Potential Impact Worksheet was developed to systematize the analysis of the ratings assigned to the various factors and subfactors previously described. Six steps are identified at which specified tasks are performed. The first step is to identify Potential Impact Areas. A Potential Impact Area is that part of the drainage area of a project which potentially could contribute sediment to a point on a watercourse, through erosion and transport. Thus, the highway project is visualized as a number of potential impact areas varying in size and potential to contribute to erosion and sedimentation impacts.

Once the potential impact areas have been identified the appropriate data as described in the guidelines proper is collected and the Net Sediment Yield Rating is determined. Ratings for the five factors making up this Net Sediment Yield Rating are determined, are summed and an overall rating is determined. This overall rating is taken to Step 5.

In Step 3 the rating for the Inability of the Surface Water to Absorb Sediment is determined from Table IV, entered at B and taken to Step 5.

Similarly a rating is determined for Step 4 where the Overall Sensitivity Rating of the Watercourse is determined. It is important to note that in this step the highest of the ratings determines the Overall Sensivity Rating. This is to ensure that the most important component is the prime determinant of sensitivity.

In Step 5, the ratings for the Sediment Yield Rating is multiplied by the rating for the Inability to Absorb Sediment and the Sediment Impact Rating is determined.

In Step 6 the results from Step 5 and Step 4 are summed in a rating for the Degree of Potential Impact.

The system has been designed so that if a high Net Sediment Yield rating (Step 2) is obtained, the rating for the Inability of Surface Water to Absorb Sediment is high and the Degree of Sensitivity is low (Step 4), the Sediment Impact Rating (Step 5) will be high while the Degree of Total Potential Impact (Step 6) will emerge as a medium indicating that some erosion control measures are needed to the extent of reducing the Degree of Total Potential Impact to a low rating.

Conversely, if there is a low rating in Step 2, a high rating for Step 3 and a high rating for Step 4 the Sediment Impact Rating (Step 5) will be 2 and the Degree of Total Potential Impact will be high. In such a case, there is no way in which the design can be revised to reduce the amount of erosion and sedimentation. Thus the only action that can be taken is to ensure that the contract is comprehensive enough to allow for the correction of any mistakes in judgement that would result in the contribution of sediment to the watercourse.

The system has been designed so that, in the event of a medium or high rating for Degree of Total Potential Impact (Step 6) the planner/designer can re-examine the ratings in the various steps to determine if the individual factor ratings can be reduced by modifications to the design, thus attempting to lower the Degree of Potential Impact to a low rating. If such modifications can be done at reasonable cost and without undue impacts on other factors, the objectives of the project should be attained and a better project should result.

In the event where it is impossible or impractical to develop a conceptual design and construction approach through the iterative process described, and a high degree of potential impact is still present, a more rigorous examination involving perhaps the calculation of erosion contributions from individual slopes using the Universal Soil Loss Equation in an interative manner of alternative generation and analysis would be appropriate.

FIGURE I - TOTAL POTENTIAL IMPACT WORKSHEET

Step 1 - Identification of Potential Impact Areas W.P. _____

Location _____

Step 2 - Sediment Yield

A. Circle Ratings of Individual.

Factors	High	Med.	Low
1. Runoff	3	2	1
2. Soil Erodibility	3	2	1
3. Topography	3	2	1
4. Area of Const'n.	3	2	1
5. Location	3	2	1

B. Sum Ratings [ ]

C. Determine Net Sediment Yield Rating [ ]

High = 3, if sum = 13-15
Med. = 2, if sum = 8-12
Low = 1, if sum = 5-7

Step 3 - Inability of Surface Water to Absorb Sediment

A. Circle Rating

High	Med.	Low
3	2	1

B. Enter Rating [ ]

Step 4 - Degree of Sensitivity

A. Circle Ratings of Individual

Factors	High	Med.	Low
1. Aquatic Ecosys'n.	3	2	1
2. Recreation	3	2	1
3. Consumption	3	2	1
4. Water Eng. Facilities.	3	2	1

B. Highest Individual Rating = Overall Sensitivity Rating [ ]

High = 3
Med. = 2
Low = 1

[ ] X [ ] = [ ]

Step 5.

A. Multiply Sediment Yield Rating by Inability to Absorb Sediment Rating to Determine Sediment Impact Score.

B. Determine Sediment Impact Rating [ ]

High = 3 if Score is 9,6
Med. = 2 if Score is 4,3
Low = 1 if Score is 2,1

[ ] + [ ] = [ ]

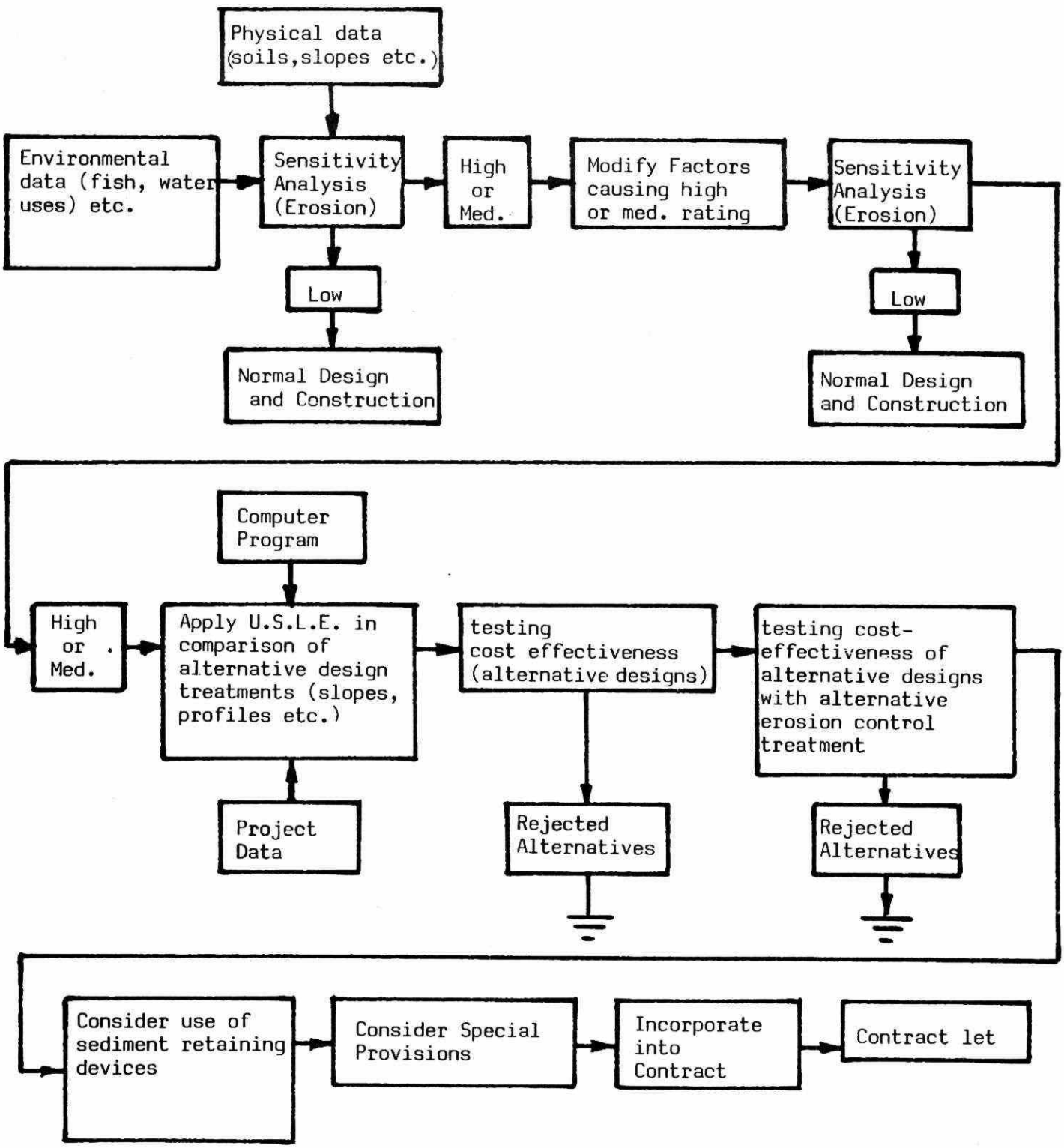
Step 6.

A. Add Sediment Impact Rating to Sensitivity Rating for Total Potential Impact.

B. Determine Degree of Total Potential Impact [ ]

High, if Sum = 6,5
Med., if Sum = 4
Low, if Sum = 3,2

FIGURE II


Physical data (soils,slopes etc.)
Environmental data (fish, water uses) etc.
Sensitivity Analysis (Erosion)
High or Med.
Modify Factors causing high or med. rating
Sensitivity Analysis (Erosion)
Low
Normal Design and Construction
Low
Normal Design and Construction
Computer Program
High or Med.
Apply U.S.L.E. in comparison of alternative design treatments (slopes, profiles etc.)
testing cost effectiveness (alternative designs)
testing cost-effectiveness of alternative designs with alternative erosion control treatment
Project Data
Rejected Alternatives
Rejected Alternatives
Consider use of sediment retaining devices
Consider Special Provisions
Incorporate into Contract
Contract let

In such a case, the approach would be to examine the effects of modifying the slopes of the project in conjunction with other means associated with reducing the contribution of eroded materials from exposed slopes. Often the flattening of slopes combined with an early application of a highly efficient cover on the exposed soils will reduce the problem greatly; the calculations are probably of most value in detailing the degree of slope flattening, the type and amount of material to be applied and the timing.

Figure II presents a flow diagram to show where the sensitivity analysis technique just described fits into the preliminary design stage of highway project development.

5.0 Erosion and Sedimentation Control Problem Areas

During the site planning and construction stages, particular attention should be given to the seven eroison and sedimentation control problem areas identified by (8). These areas are:

slopes
streams and waterways
surface drainageways
enclosed drainage inlet and outfall control
large flat surface areas
borrow areas
adjacent properties

5.1 Slopes

Run-off velocity increases as the slope gradient and slope length increases. Particular attention should be paid to the erosion potential under the following conditions:

(a) slopes are steep
(b) slopes are without vegetation
(c) soil erodibility is high

Combinations of the above three conditions often occur in which case, the erosion potential will be particularly high.

5.2 Streams and Waterways

There are several characteristics that serve to identify streams and waterways that are particularly vulnerable to erosion. Streams which have a small channel capacity with steep banks which will create high velocities at times of storm run-off are very susceptable to erosion. In general, wherever exposed erodible soil along a stream bank is found especially in conjunction with a restricted channel, or sharp turns, corrective measures will have to be taken especially if the resulting development will itself result in an increase in peak flows.

5.3 Surface Erosion

Whenever water is collected in a drainageway before discharge to an outlet, its potential to erode is increased especially under the conditions experienced at construction sites. It is here where it is especially important to slow the water down - make it walk, rather than run. Often, because of the problems caused by the retardation of flows, this will only be practical in cases of low flows. The stabilization of drainageways will, therefore, have to be conducted.

5.4 Enclosed Drainage: Inlet and Outfall Control

Because of the increase in peak flows that often occurs as a result of the reduction in the retention of water on the site, stabilized drainageways may be inadequate to handle the flows without erosion. In such a case, enclosed storm sewers can safely convey run-off of high concentrations and velocities.

The installation of storm sewers before major building construction begins can aid in controlling site run-off and in avoiding erosion hazards. Where storm sewers are installed early in the site development, the inlets can be so modified to form sediment traps which will cause the settlement of large-sized particles which otherwise would become trapped in the catch basins or transported to the outlet. A number of designs are available which involve either the excavation of the sediment trap with the inlet serving as the riser pipe or the use of various filter media to increase the depth of water in the drainage channel. In all cases, prompt attention must be paid to the excavation of accumulated sediments if the structures are to function adequately.

5.5 Large Flat Surface Areas

All areas of exposed soil are vulnerable to erosion. Clearing, grading and vegetative restabilization in these cases can be timed so that the extent of exposed area and the duration of exposure can be minimized (see Section 2.5.1) Temporary seeding or mulching is required where large areas will not be permanently stabilized within recommended time limits.

5.6 Borrow and Stockpile Areas

Borrow and stockpile areas, because they consist of exposed soil, need to be considered as significant sources of soil erosion, expecially in those cases where significant environmental impacts may occur. Under such cases, the three principles mentioned previously should be employed. In the case of stockpile areas, the location should be well

thought out in order that such piles are not located so as to contribute sediment to potential impact areas. However, there is seldom any valid reason for leaving a stockpile area unvegetated; the cost of temporary seeding is insignificant in cases where environmental impacts are potentially high.

5.7 Adjacent Properties

The protection of adjacent properties from accelerated erosion and sedimentation is an important concern. The earth-changer has a moral responsibility, if indeed not a legal responsibility to ensure that his work is of sufficient high quality so as to not create erosion and sedimentation problems on adjacent properties. The retention of sediment within the boundaries of the developing area and the design of the drainage system so that peak flows are accomodated by the drainageway on the adjacent property must be given the same consideration as is given to deal with similar situations within the developing area.

6.0 Erosion and Sedimentation Control Practices

Appendix I provides a list of most of the known erosion and sedimentation control practices along with an indication of relative costs and effectiveness. Although prepared from literature on erosion and sedimentation control practices on highway rights-of-way, many of the same practices are applicable to developing urban areas.

Erosion and sedimentation control practices generally fall into one or a combination of these categories:

(1) vegetative
(2) structural
(3) chemical
(4) procedural - management

6.1 Vegetative Erosion and Sedimentation Control Practices

The use of vegetation of various types according to the soil type, climate, time of year, aspect etc. is one of the better known methods for controlling erosion. These practices always involve the use of either processed or living plant material so as to reduce the exposure of soil to rainfall or flowing water. Not only is vegetation used to reduce erosion, but it is also used to promote sedimentation and is employed in such techniques as vegetative buffers around construction sites and in hay or straw-bale sediment settlers.

Vegetative practices can be further broken down into:

(a) vegetative transplants
(b) seeding
(c) mulching

6.1.1 Vegetative Transplants

The use of vegetative transplants consists of the transfer of living vegetative material from a growing site to an area to be stabilized. Sodding is a common example, although the transplanting of trees and shrubs also falls into this category.

In general, vegetative transplants have the main advantage of providing an "instant" cover although some special care is needed before the new roots establish themselves in the new site. In general, the practices cost considerably more than other practices involving the stabilization of large areas.

6.1.2 Seeding

The application of seed to a prepared seedbed is a very common and relatively inexpensive erosion control practice. The application of seed is usually accompanied by the application of a mulch and/or a nurse crop in order to not only provide for erosion protection during germination and grewth, but to also modify the micro-climate of the seeds so that the maximum germination possible is practically ensured. However, because of the length of time required for the young seedlings to anchor the soil particles, erosion, in the form of rills and gullies, may cause damage to the slope. The use of this practice is practically useless by itself for late seeding before winter, since a temperature of approximately 42!F is generally required for germination. The chief advantages are the low cost and the large area that can be treated in a short period of time.

6.1.3 Mulching

The use of mulch is similarly of widespread usage, since it too is inexpensive and will treat a large area in a short period of time. Traditionally, mulching materials consisted of straw or hay. In recent times, however, a variety of materials have been put on the market. One product consists of finely ground wood fibres with a tack and a green colouring. Another product utilizes a mixture of shredded newspapers, woodchips and waste raw cotton. Still another, called Excelsior Blanket, consists of wood excelsior contained within a plastic net.

A variety of tacks can also be used with the mulch in order to provide a degree of stability against the effects of wind and water. One of the commonest tacks is asphalt. A rather innovative mechanical means of integrating the mulch to the soil has been tried sucessfully by the Ministry of Transportation and Communications. This practice consists of a heavy application of straw mulch (up to 2") following seeding. The seed and straw are then integrated into the soil by running a heavy bulldozer having deep cleats perpendicular to the slope so that the straw and seed is "punched" into the soil by the cleats. The straw not only provides a favourable micro-climate for seed germination, but is anchored ot the soil while the cleats ensure the contact of seed with the mineral soil while, at the same time, trap moisture and sediment to act as mini-sedimentation traps.

Very seldom is mulching utilized without an application of seed because the extra cost of the seed is relatively insignificant and, since the mulch serves a major protective function for the germinating seed. The typical application rate for straw mulch for M.T.C. highway construction projects is 1 to 1.5 tons per acre.

6.2 Structural (Mechanical) Erosion and Sedimentation Control Practices

This group includes by far the greatest number of erosion and sedimentation control practices. In general, they can be grouped into six cateogories according to function as follows:

(a) retention,

(b) diversion
(c) energy attenuation
(d) slope modification
(e) surface modification
(f) filtration.

As in the case of the vegetative practices described earlier, combinations of these six categories are prevalent.

6.2.1 Retention

The retention of water is to not only reduce the erosive power of water, but is to permit the settlement of the sediment load. There are many different types of retaining devices, but the most common is probably the sediment trap or basin (sediment settler). A sediment settler can range from a simple hole in the ground in a drainage channel to an elaborate pond complete with an earthen dam and a spillway controlling a water area of up to one acre. In all cases, the objective is the same: to remove unwanted sediment. The effectiveness of the larger sediment settlers in the removal of the smaller sized particles is vastly greater than the smaller settlers. The cost of such settlers is often justified, however, by the need to reduce the sediment load to an extent that it will have a minimum effect on downstream water quality.

Sediment settlers can also be made from gabions (10), straw bales (11) sandbags (10), and possibly logs. It may be noted that the use of gabions and straw sediment basins also make use of a filtering principle, but it should be pointed out that the pores in such a filtering mechanism soon clog with sediment so that the structure more properly acts as a dam. Reference (12) provides good examples an how to relate the size of the sediment settler to the design storm.

6.2.2 Diversion

The purpose of diverting water is to prevent flowages onto and over areas of the job where erosion might be particularly damaging. Diversions can be used to intercept storm water before it reaches disturbes slopes or other exposed areas. They can also be used to collect run-off and convey it to a sediment settler.

Generally, diversions are created by the earth-changer by the shaping of soil surfaces so as to direct water to a desirable location. The use of terraces and benches in steep cuts serve to prevent the increase in the concentration of water as it flows down the slope by collecting it on the terrace or bench and taking it to a suitable outlet otherwise the concentration and high velocity that would be experienced near the base of the cut would result in deep rills and gullies. The use of diversion applies the second principle mentioned above - make the water walk, not run. At the same time, the retention of sediment can be accomplished if the diverted water is made to move slowly along the terrace or bench.

The creation of a diversion can easily be accomplished by the use of an earth grader to grade a furrow of earth above a particularly erodible area. The water is taken along the base of such a furrow and deposited at a location where the concentration and velocity of water can be safely taken down the slope by way of a downpipe of channel without causing damage through the creation of gullies.

Diversions can also be created by the use of corrugated steel pipes cut lengthwise and anchored in the preformed diversion, by the use of rip-rap, gabions installed over a suitable filter blanket, or, in temporary situations, by the use of properly anchored sod. A recent development has been the use of filter blanket alone in ditch bottoms.

A common use of diversions is to relocate stream courses around a work area. Although the construction of such a diversion will result in some turbidity, the degree of turbidity will be largely determined by the procedures used and the degree of consideration of erosion protection applied to the diversion.

6.2.3 Energy Attenuation

Energy attenuation devices are commonly used in engineering practice; these applications, although designed and used to prevent damage to structures by erosion, will not be dealt with here. The second principle of making water walk is involved. Any mechanical technique that will slow the water velocity is an energy attenuating device. A common example is the use of rip-rap in steep ditches while sod is often used in ditches with a lower gradient. In such applications, the rocks or the blades of grass serve to slow the velocity of water. At the same time, these materials prevent the transfer of energy to soil particles with their consequent movement in the erosion process.

Where long, steep gradients are involved, energy attenuations are commonly constructed by imbedding bricks, concrete blocks or rocks into the concrete or asphalt ditch lining so that the force of water moving down the slope drain will be retarded and its energy attenuated.

The use of check dams, weirs and drop spillways made of a variety of materials, both temporary and permanent, will reduce channel grade and dissipate the energy of flowing water.

Special care has to be taken that the energy attenuation device will adequately dissipate the energy of the water so not to damage banks or the toe of the structure. It should be noted that energy attenuation devices frequently result in a concentration of the volume of the water flow with a consequent increase in water velocity at the structure and, therefore, banks around grade control structures often require additional stabilization measures.

6.2.4 Surface Modification

Surface modification entails the use of some mechanical means of reducing soil erosion through the modification of the surface so as to prevent a transfer of energy between moving water to individual soil particles. A variety of materials are commonly used. Crushed stone, although expensive, might be used especially in those locations where such a material might form the base of proposed roadways, parking areas, etc. The use of such material, however, would be inappropriate where the anticipated land use was for lawns, parks, etc. where a grass sod was the desired cover.

The use of plastic sheeting to prevent dislodgement of soil through rain drop impact has been used; for example, during the construction of the C.N. Tower. The use of this technique, however, must consider the practical aspects; holes in the plastic cover might allow a concentrated flow onto the soil beneath the sheeting unless adequately anchored and the placement and maintenance might result in higher costs than perhaps the use of vegetative covers.

Other means of surface modification include the use of vegetative mulches especially to reduce the effects of falling raindrops. This technique involves the use of the first principle of minimizing the exposure of soil. Its effectiveness can be enhanced through crimping the mulch so as to create a series of small depressions which will not only serve to hold the mulch, but will also assist in retaining sediment through the application of the second principle.

The use of paving materials will accomplish the same objective, but may result only in transferring the erosion problem to some other location.

6.2.5 Slope Modification

In those circumstances where steep slopes will result in an unacceptable level of erosion, the flattening of those slopes should be considered as an erosion control practice. The use of retaining walls incorporated into a slope will allow the flattening of slopes above and below the structure within the same horizontal cross-section. Where slopes are steep and it is possible to flatten such slopes to blend into the development, this technique will certainly reduce the LS factor in the U.S.L.E. with a consequent reduction in erosion potential.

It should be noted that the incorporation of a grade control structure into a stream not only serves as an energy attenuator but reduces stream gradient upstream and downstream of the structure.

6.2.6 Filtration

The use of filtration techniques frequently involve the retention of water so that sediment carried in water is removed as the water seeps through the filtering media.

One common and inexpensive application of this technique involves the blockage of a temporary water flowage with a truck load of granular material. The granular material (eg. Granular A or B) will act as a dam and will result in the creation of a head of water which will allow the passage of water through the granular material. The sand content of the granular will tend to retain sediment. It should be noted that the granular material will eventually become clogged so that the granular will increasingly become more efficient as a sediment basin. The danger exists, however, that as the granular becomes clogged with sediment, the head of water will increase with the consequent possibility of flowages around the structure. It is therefore only a temporary measure.

A recent application of the filtering mechanism involves the erection of filter cloth vertically on a fence in such a way that water carrying sediment is impounded being such a fence and is filtered as it passess through the filter cloth. Again, as the pores of the filter cloth become clogged, the structure increasingly behaves as a dam causing the settling of sediment.

6.3 Chemical

Various chemical means have been developed which will change the properties of the soil surface generally by aggregating the fine soil

particles into larger aggregations. Thus the K factor of the U.S.L.E. is reduced. One chemical formulation is a mixture of fractionated plastic in a glue-like liquid. The mixture, when sprayed on soil, aggregates the soil particles but allows the passage of water into the soil especially in those places where slight ponding occurs. It has been found that the use of this material is not effective where large stones predominate in the cut (ie. stony tills). It is probably more effective where soil particle sizes are rather uniform and small.

The use of an asphalt tack in conjunction with a vegetative mulch has already been discussed. An asphalt tack, however, can be used without a mulch. Such an application, however, may not present an aesthetic appearance, especially in an urban area.

Synthetic materials, such as fibreglass are sometimes used as a substitute to vegetative mulches. Such materials, however, are not always biodegradable and may create long term aesthetic and maintenance problems.

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APPENDIX

EROSION CONTROL MEASURES
ROADWAY DITCHES

TREATMENT PRACTICE	DEFINITION	OBJECTIVE	ADVANTAGES	PROBLEMS	COST RATING	EFFECTIVENESS RATING
Check Dams	Structure used to stabilize grade or to control head cutting in natural or artificial channels.	To reduce or prevent excessive erosion by reduction of velocities or by providing partial lined channel sections or structures that can withstand high flow velocities.	Maintain low velocities. Catch sediment. Can be constructed of logs, shot rock, lumber, masonry, or concrete.	Close spacing on steep grades. Require clear-out. Unless keyed at sides and bottom erosion may occur.	Low to High	High
Sediment Barriers	Temporary barriers or diversions that are constructed of sandbags or straw bales.	Retain sediment on site by retarding and filtering storm runoff.	Can be located as necessary to collect sediment during construction. Clean-out often can be done with on the job equipment. Simple to construct.	Little direction on spacing and size. Sediment disposal may be difficult. Specifications must include provisions for periodic clean-out. May require seeding, sodding or pavement when removed during final clean-up. Target for vandals. Of little value in roadside ditches with even slight grades. Must be replaced when rotten or disintegrating.	Low to Medium	Medium
Filter Berm	Temporary ridge of gravel or crushed rock.	Retain sediment on-site by retarding and filtering run-off in ditches prior to roadway paving and establishment of permanent ground cover.	Formal design not required.	Removal of trapped sediment and clean-out or replacement of clogged filter material after each storm.	Low	Medium
Sediment Retention Basin	Temporary dam or basin or a combination of both.	Trap and retain sediment generated during construction activities on-site.	Can be located as necessary. Simple to construct.	Little direction on spacing and size. Sediment disposal may be difficult. Periodic clean-out required. May require seeding, sodding, or pavement when removed during final clean-up. Fine sediment will not settle out in basins with short detention periods.	Low to Medium	Medium to High

ROADWAY DITCHES CONTINUED...

TREATMENT PRACTICE	DEFINITION	OBJECTIVE	ADVANTAGES	PROBLEMS	COST RATING	EFFECTIVENESS RATING
Ditch Inlets	A catch basin in the ditch.	To redirect surface runoff into storm sewer system.	Sediment can collect in sumps.	Expensive. Care taken to prevent erosion at outlet of sewer pipe. Does not filter out fine material as retention time too short.	High	High
Sodding	Stablizing ditches with grass sod.	To stablize the ditch, to reduce damages from sediment and runoff to downstream areas.	Easy to place with a minimum of preparation. Can be repaired during construction. Immediate protection. May be used on sides of paved ditches to increase capacity.	Requires water during first few weeks. Sod not always available. Will not withstand high velocity or severe abrasion from sediment load.	Medium	Low-Medium
Seeding/Mulching	Application of seed with an organic or inorganic material mixed in to facilitate germination and hold the seed in place.	To provide vegetative covering as early as possible to reduce erosion. The mulch provides temporary erosion protection until grass is established.	Usually least expensive. Effective for ditches with low velocity.	Will not withstand medium to high velocity.	Low	Medium to High
Paving, Riprap, Rubble	Lining ditches with pavement, riprap, or rock rubble.	To prevent ditch erosion where high flow velocities are expected.	Effective for high velocities. May be part of the permanent erosion control effort. Minor repairs relatively easy.	Cannot always be placed when needed because of construction traffic and final grading and dressing. Initial cost is high.	High	High in preventing ditch erosion. Low for retaining sediment.
Erosion Check	Porous, mat-like material installed in a slit trench oriented perpendicular to direction of flow in ditch.	Prevents formation of rills and gullies by permitting subsurface water migration without removal of soil particles and by providing positive grade control of subsurface flow.			Low	Medium
Half-Culvert (Spillways)	A half section of corrugated steel pipe placed in a ditch.	To prevent erosion of ditch itself.		Energy dissipators and sedimentation basins often required. Steel pipe may become undercut such that function as a control factor is completely lost. Erosion may occur at outlets unless precautions taken. Sediment entering it is carried straight through.	Medium	Medium

ROADWAY DITCHES CONTINUED.....

TREATMENT PRACTICE	DEFINITION	OBJECTIVE	ADVANTAGES	PROBLEMS	COST RATING	EFFECTIVENESS RATING
Sub-drains Perforated Steel Pipe	Pervious back filled trenches containing a pipe with perforations or open joints for the purpose of intercepting ground water or seepage.	Used to draw off surface water, lowers water table, reduces seepage.	Reduces erosion hazard in ditch by reducing surface water flow.		Medium	High
Excelsior Blanket	Protective blanket used in the establishment of vegetation in critical areas.	As a mulch it conserves soil moisture, serves as an insulator against intense solar insolation, dissipates energy from falling raindrops and reduces erosion caused by overland flow.	Resistant to erosion by concentrated storm runoff. Can be used in critical areas such as swales, ditches, steep slopes, highly erodible soil etc.	Poor adherence to soil.	Very High	Medium
Fiberglass Matting	Flexible fiberglass made of inorganic materials that will not rot, corrode or burn.	Used in construction of erosion checks and as a mulch for seedbeds.	Can be used as a mulch blanket where long-term resistance to erosive forces is desired in conjunction with vegetation.	Poor adherence.	Very High	Medium
Glassroot	Fiberglass mulch product for use on newly seeded areas.	As a mulching product it conserves soil moisture, insulates against intense solar energy, dissipates energy from falling raindrops and reduces erosion caused by overland sheet flow.	Will not react or decompose when exposed to water, sunlight or chemicals found in the soil.	Difficult to handle.	Very High	High
Jute Netting	Heavy woven jute mesh of rugged construction used in establishment of vegetation.	As a mulch, conserves soil moisture, insulates against intense solar isolation, dissipates energy from falling raindrops and reduces erosion caused by overland flow.	Can withstand the higher flow velocities associated with critical swales, ditches, median strips etc.	Use of erosion checks in conjunction may be required. Unavailable.	Very High	High
Mulch Blankets	Composite of cellulose fibers bonded together into a blanket to be used in establishment of vegetation in critical areas.	As a mulching product, conserve soil moisture, insulate against intense solar radiation, dissipate raindrop energy, and reduce erosion caused by overland flow.		Cost of application high.	Very High	Medium

ROADWAY DITCHES CONTINUED.....

TREATMENT PRACTICE	DEFINITION	OBJECTIVE	ADVANTAGES	PROBLEMS	COST RATING	EFFECTIVENESS RATING
Netting	Natural or synthetic fiber mulch securely anchored on seeded areas or areas temporarily stabilized with mulch tacking products which are insufficient.	To hold seed in place and also to reinforce newly placed turf that may be subject to severe runoff velocities before turf has taken proper hold.		Not flexible. After growth started, ineffective as erosion control.	Very High	Medium
Plastic Filter Sheet	Cloth woven of polypropylene monofilament yarns secured to soil surface with securing pins and staples with fiberglass rods.	Replacement for graded filter systems and filter blankets in conjunction with many hydraulic structures.		Poor adherence to soil.	High	Medium
Straw or Hay	Straw or hay used as a mulch product on newly seeded areas or as a temporary measure to protect bare soil areas that have not been seeded.	As a mulch, conserves soil moisture, insulates against intense solar energy, dissipates raindrop energy and reduces erosion caused by overland flow.	Can be applied by hand spreading on small plots and by mulch blowing equipment on larger areas.	Straw and hay mulch should be tacked to protect against wind and water erosion. Concentrated flow will wash straw and hay off.	Low	Medium
Woodchips	Chips of wood produced by processing tree trunks, limbs, branches etc. in wood chipping machines.	1. Temporary or interim erosion control technique to protect bare soil areas that have not been seeded. 2. Mulch product on newly seeded areas.	Useful as a mulch when used with late fall seeding operations that require protection over winter. Reduce amount of open burning.	Equipment availability. Do not produce good growth.	Medium Medium	High Low

ROADWAY SURFACE

TREATMENT PRACTICE	DEFINITION	OBJECTIVE	ADVANTAGES	PROBLEMS	COST RATING	EFFECTIVENESS RATING
Crowning to Ditch or Sloping to Single Berm	Grading the road so that run-off flows off into ditch or a berm.	Directing surface water to a prepared or protected ditch to minimize erosion control runoff.	Easy to construct.	None - should be part of good construction procedures.	Low	High
Compaction	Mechanical compressing of subgrade or granular courses to optimum density.	To reduce erosion, loose or uncompacted material is more subject to erosion. Final lift of each day's work should be well compacted and bladed to drain to ditch or berm section.		None - should be part of good construction procedures.	Low	High
Aggregate Cover (Gravel Sheeting)	Blanket of granular material on roadway surface.	Provide a material which is not easily eroded.	Minimizes surface erosion. Permits construction traffic during adverse weather.	Requires working and compaction if exposed for long periods of time. Loss of surface aggregates can be anticipated.	High	High
Filter Berm	Temporary ridge of gravel or crushed rock constructed across a graded right-of-way that is not subject to vehicular traffic.	Retains sediment on-site by retarding and filtering run-off while at the same time allowing construction traffic to proceed along right-of-way.	Easy to construct.	Removal of trapped sediment and cleanout or replacement of clogged filter material after each storm.	Low	Medium
Interceptor Dike	A temporary ridge of compacted soil constructed across a graded right-of-way that is not subject to vehicular traffic	Reduce erosion by intercepting storm runoff and diverting it to temporary outlets where it can be disposed of with minimal erosion.		Inspect after each storm. Repairs must be completed before next storm to ensure against structural failure.	Low	Medium
Paved Gutter	Paved asphalt gutters constructed at the outer edge of the paved shoulders.	To protect shoulders on steep grades and prevent erosion of the slopes.		Erosion control such as slope drains or catch basins required at outlet.	Medium	High

CUT SLOPES

TREATMENT PRACTICE	DEFINITION	OBJECTIVE	ADVANTAGES	PROBLEMS	COST RATING	EFFECTIVENESS RATING
Berm top of cut.	Earth ridge constructed along top edges of embankments.	To divert water from cut slope and collect it for slope drains/paved ditches.	May be constructed before grading is started. Minimizes disturbance of existing vegetation when used rather than diversion terraces.	Access to top of cut. Difficult to build on steep natural slope or rock surface. Concentrates water and may require channel protection or energy dissipation devices. Can cause water to enter ground, resulting in sloughing of the cut slope.	Low	Medium to High
Diversion Dike	A temporary ridge of soil constructed at top of cut or fill slopes combined with a crown ditch to intercept surface runoff from the slope above and conduct it to slope drains or natural water courses on milder slopes.	Collects and diverts water from cut slope to reduce erosion.	May be incorporated in the permanent project drainage.	Access for construction. May be continuing maintenance problem if not paved or protected. Disturbed material or berm is easily eroded.	Low	Medium to High
Slope Benches	Large steps or benches cut into slope.	To slow velocity of surface water and collect sediment.	Provides access to slope for seeding, mulching and maintenance. Collects water for slope drains or may divert water to natural ground.	May cause sloughing of slope if water infiltrates. Requires additional right-of-way. Not always possible due to rotten material etc. Requires maintenance to be effective. Increases excavation quantities.	Medium	Low to Medium
Slope Drains (Pipe, Paved etc.)	A channel of concrete, pipe etc. to conduct surface runoff from the top of a slope to the bottom of the slope.	To collect surface water and thereby reduce erosion on the slope.	Can be temporary or part of permanent construction. Can be constructed or extended as grading progresses.	Requires supporting effort to collect water. Permanent construction is not always compatible with other project work. Usually requires some type of energy dissipation.	High	High
Seeding/Mulching	Application of seed with an organic or inorganic material mixed in to facilitate germination and hold the seed in place.	To provide vegetative covering as early as possible to reduce erosion. The mulch provides temporary erosion protection until grass is rooted.	Temporary or permanent seeding may be used. Larger slopes can be seeded and mulched with smaller equipment if stage techniques are used.	Difficult to schedule high production units for small increments. Time of year may be less desirable. May require supplemental water.	Low	High once grass established.

CUT SLOPES CONTINUED.....

TREATMENT PRACTICE	DEFINITION	OBJECTIVE	ADVANTAGES	PROBLEMS	COST RATING	EFFECTIVENESS RATING
Seeding/Mulching Continued.....				Contractor may perform this operation with untrained or unexperienced personnel and inadequate equipment if stage seeding is required.		
Sodding	Stabilizing erosive areas with grass sod.	To stabilize slopes immediately, thereby reducing erosion.	Provides immediate protection. Can be used to protect adjacent property from sediment and turbidity.	Difficult to place until cut is complete. Sod not always available. May be expensive.	Medium	Medium to High
Slope pavement, riprap.	Covering the slope with a layer of pavement or riprap.	To provide immediate protection for high risk areas and order structures.	May be cast in place or off site.	Expensive. Difficult to place on high slopes. May be difficult to maintain.	High	High
Granular Blanket	A 1' to 2' thick blanket of material such as Granular Base Course Class "B" placed evenly over the surface of slopes comprised of very erosive soils.	To provide a stable, free draining slope material. Particularly suitable when ground water emerges through the surface soil.			High	High
Temporary Plastic Cover	Plastics in wide rolls and large sheets placed over slope.	To provide temporary protection for cut or fill slopes.	Easy to place and remove. Useful to protect high risk areas from temporary erosion.	Provides only temporary protection. Original surface usually requires additional treatment when plastic removed. Must be anchored to prevent wind damage. If not properly anchored at top, water will travel over slope under the plastic.	High	Medium to High
Serrated Slope	Steps cut to the contour in soft rock cuts.	To lower velocity of surface runoff and collect sediment. Aids in establishment of vegetated cover on decomposed rock or shale slopes.	Holds moisture. Minimizes amount of sediment reaching roadside ditch.	May cause minor sloughing if water infiltrates. Construction compliance.	Low	Medium

CUT SLOPES CONTINUED.....

TREATMENT PRACTICE	DEFINITION	OBJECTIVE	ADVANTAGES	PROBLEMS	COST RATING	EFFECTIVENESS RATING
Level Spreader	An outlet constructed at zero grade across a slope where concentrated runoff may be spread at non-erosive velocities over undisturbed areas stabilized by existing vegetation.	To convert concentrated flow into sheet flow for outlet at non-erosive velocities onto areas stabilized by vegetation.	Formal design not required.	Outlet lip must be exactly level and uniform from end to end or concentrated flow and consequent erosion of stabilized area will result. Only built where spreader on undisturbed soil and where area directly below level lip is stabilized by vegetation.	Low	Medium
Intercepting Ditch	Ditches constructed in the form of benches in the cut slope.	To check velocity of flow on the slope and thereby control erosion.			Medium	High
Subdrains (Perforated pipe)	Pervious backfilled trenches containing a pipe with perforations or open joints for the purpose of intercepting ground water or seepage.	Used to draw off surface water. Lowers water table, reduces seepage. Partly directed toward slope stability and erosion control.		Pipe may become filled with sediment.	Medium	High
Roughness and Scarification.	Roughness is the uneven or bumpy condition of the soil surface. Scarification is the process of loosening or stirring the soil to shallow depths without turning it over.	Slows down flow velocity and enhances water infiltration.	Improves seeding and sodding success.		Low	Medium
Chemical Soil Stabilizers, Mulches and Mulch Tacks	Chemical emulsions sprayed on denuded surfaces, seeded and mulched surfaces or mixed in with seed/mulch mixture.	1. Temporary soil stabilization. 2. Chemical mulch. 3. Mulch tack.	Can be used to protect denuded soil from wind and water erosion during delays in grading operations during hot and dry periods, after final grading, or until permanent seeding is possible.	Special spray equipment required. Cannot be applied in sub-freezing weather.	Medium	High
Fiber Mulches) Mulch Blankets and) Nettings)	SEE ROADWAY DITCHES					

FILL SLOPES

TREATMENT PRACTICE	DEFINITION	OBJECTIVE	ADVANTAGES	PROBLEMS	COST RATING	EFFECTIVENESS RATING
(Diversion Dike) Berms at Top of Embankment.	Earthen or soil cement dikes constructed along shoulders of roadways.	To prevent runoff of embankment surface from flowing over fill slopes and thereby reduce erosion hazard.	Collect runoff for slope drains or protected ditch. Can be placed as a part of the normal construction operation and incorporated into fills or shoulders.	Cooperation of construction operators to place final lifts at edge for shaping into berm. Failure to compact outside lift when work is resumed. Sediment buildup and berm failure.	Low	Medium to High
Slope Drains	Channels of concrete, pipe etc to conduct surface runoff from the top of slope to the bottom of the slope.	To prevent fill slope erosion caused by embankment surface runoff.	Can be constructed of full and half section pipe, bituminous, metal, concrete plastic, or other waterproof material. Can be extended as construction progresses. May be either temporary or permanent.	Permanent construction as needed may not be considered desirable by contractor. Removal of temporary drains may disturb growing vegetation. Energy dissipation devices required at outlets.	High	High
Fill Berms or Benches	Large steps or benches constructed on a fill slope.	To slow velocity of slope runoff and collect sediment.	Provides access for maintenance. Collects water for slope drains. May utilize waste.	Requires additional fill material if waste is not available. May cause sloughing. Additional right-of-way may be required.	Low	Low - Medium
Seeding/Mulching	Application of seed with an organic or inorganic material mixed in to facilitate germination and hold the seed in place.	To reduce erosion by providing a protective cover thereby decreasing the period a slope is left bare.	Mulch that is cut in or otherwise anchored will collect sediment. The furrows made will also hold water and sediment.	Seeding season may not be favourable. Not 100% effective in preventing erosion. Water may be necessary. Steep slopes may require supplemental treatment.	Low	High when vegetation established.
Sodding	Stabilizing silt - producing areas with grass sod.	To stabilize the area, to reduce damages from sediment and runoff to downstream areas.	Provides immediate protection.	Material not always available. Application during dry periods requires additional care. Sod may slump.	Medium	Medium to High
Roughness and Scarification.	To roughen slope surface by discing and light scarification	Slows down flow velocity and enhances water infiltration.	Improves seeding and sodding success. No special equipment required.		Low	Medium

FILL SLOPES CONTINUED.....

TREATMENT PRACTICE	DEFINITION	OBJECTIVE	ADVANTAGES	PROBLEMS	COST RATING	EFFECTIVENESS RATING
Chemical Soil and Stabilizers, Mulches and Mulch Tacks	Chemical emulsions used as temporary soil stabilizers, mulches and mulch tacks.	1. Temporary soil stabilization. 2. Chemical Mulch. 3. Mulch Tack.	Can be used to protect denuded soil from wind and water erosion during delays in grading operations during hot and dry periods, after final grading or until permanent seeding is possible.	Special spray equipment required. Cannot be applied in subfreezing weather.	Medium	High
Fiber Mulches, Mulch Blankets and Nettings	SEE ROADWAY DITCHES					

PROTECTION OF ADJACENT PROPERTY

TREATMENT PRACTICE	DEFINITION	OBJECTIVE	ADVANTAGES	PROBLEMS	COST RATING	EFFECTIVENESS RATING
Brush Barriers	A barrier consisting of slashing, logs etc.	To create deposition of sediment in small fans below embankment areas.	Use slashing and logs from clearing operations. Can be covered and seeded rather than removed. Eliminates need for burning or disposal off right-of-way.	May be considered unsightly in urban areas. May be washed away in heavy rain storm.	Low	Low
Straw Bale Barriers	A barrier composed of staked straw bales.	To reduce velocity of runoff and filter sediment and some turbidity from runoff.	Straw is readily available in most areas.	Require removal. Subject to vandal damage. Flow is slow through straw requiring considerable area.	Low	Medium
Sediment Traps	Temporary dam or basin or a combination of both that will trap and store sediment produced on exposed areas and delivered to the structure by storm runoff.	Trap and retain sediment generated during construction activities on-site.	Collect much of sediment spill from fill slopes and storm drain ditches. Inexpensive. Can be cleaned out and expanded to meet need.	Does not eliminate all sediment and turbidity. Space is not always available. Must be removed (usually). Requires continuous clean out during construction.	Low	Medium
Sedimentation Basin	A temporary or permanent larger form of a sediment trap with standup pipe, emergency spillway etc.	To trap and store sediment from erodible areas in order to protect properties below the installation from excessive siltation.	Can be designed to handle large volumes of flow. Both sediment and turbidity are removed. May be incorporated into permanent erosion control plan.	Require prior planning, additional right-of-way and/or flow easement. If removal necessary, can present a major effort during final construction stage. Clean out volumes can be large. Access for clean out not always convenient.	Medium to High	High
Energy Dissipators	A structure such as concrete or wooden baffles used to reduce velocity of concentrated flows before they carry onto adjacent property.	Slow velocity to permit sediment collection and to minimize channel erosion off project.	Can be part of permanent erosion control. Durable.	Collect debris and require cleaning. Require special design and construction of large shot rock or other suitable material from project.	Low High if ditch included.	High
Level Spreaders	An outlet constructed at zero grade across a slope where concentrated runoff may be spread at non-erosive velocities over undisturbed areas stabilized by existing vegetation.	Convert collected channel or pipe flow back to sheet flow.	Avoid channel easements and construction off project. Simple to construct.	Adequate spreader length may not be available. Sodding of overflow berm is required. Must be part of a permanent erosion control effort. Maintenance forces must maintain spreader until no longer required.	Low	Medium

PROTECTION OF ADJACENT PROPERTY CONTINUED.....

TREATMENT PRACTICE	DEFINITION	OBJECTIVE	ADVANTAGES	PROBLEMS	COST RATING	EFFECTIVENESS RATING
Vegetative Filter Strip	An area of vegetative cover through which storm water must flow before it enters streams, storm sewers, conduits, adjacent property etc.	Remove some sediment from runoff water by filtering and by gravity sedimentation as the flow velocity is reduced.	Filter strips can be naturally occurring or man-made. Preservation of area only maintenance often required.	High flows could cause gully erosion. May require additional right-of-way to be effective.	Low	Medium

PROTECTION OF SURFACE WATER

TREATMENT PRACTICE	DEFINITION	OBJECTIVE	ADVANTAGES	PROBLEMS	COST RATING	EFFECTIVENESS RATING
Construction Dike	An earth dam or dike to restrain water from a construction site in the water.	1. To keep work site dry. 2. To decrease turbidity.	Permits work to continue during normal stream stages. Controlled flooding can be accomplished during periods of inactivity.	Usually requires pumping of work site water into sediment pond. Subject to erosion from stream and from direct rainfall on dike. Removal a major problem.	Low	Medium
Coffer Dam	A barrier built in the water so as to form an enclosure from which the water is pumped to permit free access to the area within.	1. To allow dry site conditions. 2. To decrease turbidity.	Work can be continued during most anticipated stream conditions. Clear water can be pumped directly back into stream. No material deposited in stream.	Expensive.	High	High
Temporary Stream Diversion	Temporary changing the channel or course of a stream.	To allow construction of culverts etc. in the dry. Reduces erosion hazard as work not done in running water.	Prepared channel keeps normal flows away from construction.	New channel usually will require protection. Stream must be returned to old channel and temporary channel refilled.	Medium to High	Medium to High
Riprap	Rock fragments lining bottoms and banks of surface waters.	To prevent erosion of surface water channel banks and bottoms.	Sacked sand with cement or stone easy to stockpile and place. Can be installed in increments as needed.	Expensive. Displace sediment when dropped into stream.	High	Medium
Temporary Culverts for Haul Roads	Pipe culverts placed at stream crossings of haul roads until completion of construction.	To eliminate stream turbulence and turbidity. To allow normal flow of surface water.	Provide unobstructed passage for fish and other water life. Capacity for normal flow can be provided with storm water flowing over the roadway.	Space not always available without conflicting with permanent structure work. May be expensive especially for larger sizes of pipe. Subject to washout.	Low to High	Medium
Rock-Lined Low-Level Crossing	Porous rock fill placed in shallow streams to permit equipment crossing.	To minimize stream turbidity.	Inexpensive. May also serve as a ditch check or sediment trap.	May not be fordable during rainstorms. During periods of low flow passage of fish may be blocked.	Low	Medium

PROTECTIVE SURFACE WATER CONTINUED.....

TREATMENT PRACTICE	DEFINITION	OBJECTIVE	ADVANTAGES	PROBLEMS	COST RATING	EFFECTIVENESS RATING
Check Dam	A structure used to stabilize the grade or to control head cutting in natural or artificial channels.	To reduce or prevent excessive erosion by reduction of velocities in watercourses or by providing partial lined channel sections or structures that can withstand high flow velocities.	Maintenance generally not required.	Could eventually silt in.	Low	High
Fabri-form Erosion Control Mats	Technique for pressure injecting fluid-mortar into flexible fabri-forms.	Provide structure, slope and grade protection both above and below the water line.	Can be used in shoreline stabilization, levee facing, channel lining, and construction of revetments and check dams. Uninterrupted storm flow.		Medium	High
Gabions	Large, multi-celled, rectangular wire mesh boxes filled with rock.	Used for construction of erosion control structures such as revetments, retaining walls, check dams, etc.	Effective as filters for coarse debris.	Limited success in filtering out fine sediments such as silt.	High	Medium to High
Plastic Curtain	A heavy plastic curtain placed in a shallow semicircle from the shore, hanging from polyurethane floats and anchored with sandbags.	To trap sediment produced from construction activities on adjacent shoreline. Reduce stream turbidity.				
Grade Control Structure	Earth embankments with pipe spillways or mechanical structures of concrete, masonry, steel, aluminum or treated wood.	Prevent excessive velocities in channels by reducing channel slope.		Safety hazard to traffic. Some of most effective structures quite costly. Vulnerable to failure. Possible scouring at ends.	High	High
Cement Lining	Permanent cement lining of watercourse.	Prevent shoreline erosion.			High	High

PROTECTION OF SURFACE WATERS CONTINUED.....

TREATMENT PRACTICE	DEFINITION	OBJECTIVE	ADVANTAGES	PROBLEMS	COST RATING	EFFECTIVENESS RATING
Sandbag Stream Check	A dam of sandbags, placed across a small stream.	To reduce flow of water, causing sediment created by upstream construction activities to be deposited.	Easily constructed. Easily repaired.	Permanent flow will reduce its effectiveness by rapid sedimentation. Will wash out with high flows. Only useful in intermittent and very small streams.	Low	Medium
Gavion Sediment Traps	A dam across a stream composed of gabions.	Filter out sediment.	Can be a temporary measure.	Erosion can occur around and under traps. Filter out large debris quite well but limited success in retaining silt. Current velocities must be low.	High	Medium
Sills	Concrete aprons along shoreline and streambanks.	Streambank and shoreline protection.			High	High
Groins	Low walls of timber, rock, concrete or steel constructed into the water at right angles to the shore of lakes and streams.	To trap sand or other water transported material. Develops beaches and protects shoreline from erosive action of waves and currents.			High	Medium
Restriction on equipment crossing streams.	Minimize number of crossings and permit them only at stable reaches of a stream.	Minimizes streambed disruption.		May necessitate a temporary stream crossing. Contractor may have to travel out of way to transport equipment to other side.	Variable	High

RESULTS OF RECENT WATERSHED PLANNING STUDIES IN METRO TORONTO

ABSTRACT

Basic changes in the hydrologic cycle caused by development, underlie many of the drainage and water management problems in urban areas. In the Metro Toronto region the area of urbanization is expected to increase by 60%. The impact of these changes on the watercourses in the region is significant; in terms of erosion, flooding and water quality. The Metropolitan Toronto and Region Conservation Authority has inventoried its watersheds and as a result of this review and the erosion and flooding problems that are forecast, has developed a Storm Water Management Program. This Program deals with the establishment of a basic Storm Water Management policy framework and certain performance criteria. It also deals with implementation through the planning process by defining a procedure whereby Storm Water Management policy can be incorporated at all levels. The Authority is of the opinion that it must play a key role in master drainage planning. It has available to it inventories of the opportunities and constraints as they exist along the watershed, including flood damage centres, erosion sites and areas where quality may be of concern. The Authority's Watershed Plan will provide a useful step in this regard.

RESULTS OF RECENT WATERSHED PLANNING STUDIES IN METRO TORONTO [1]

M. R. Garrett [2]

BACKGROUND

When each Conservation Authority in Ontario was established, a watershed inventory was compiled and a Resource Management Program proposed. As these inventories became outdated and as new technologies were developed, the need for Conservation Authorities to review and update their data bases to incorporate the state of the art became evident.

In keeping with this need for review and updating, the Province of Ontario in 1977 directed each Conservation Authority to study and investigate the watersheds within their jurisdiction and prepare and file with its member municipalities and the Minister of Natural Resources a Watershed Plan.

As early as 1974 The Metropolitan Toronto and Region Conservation Authority had recognized the need to review and update its resource management policies and programs. The preparation of a comprehensive review and management program was begun with the data base studies in 1975. The work culminated in March of 1980 with the presentation of a draft Watershed Plan to the Authority for its approval. The Watershed Plan is comprised of ten interrelated programs.

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[1] A speech prepared for:"A Seminar for '80: Practical Implementation of Storm Water Management Technique" Co-sponsored by: Ministry of the Environment and Municipal Engineers Association, Toronto, Ontario - October 20 and 21, 1980.

[2] Administrator, Water Resource Division, The Metropolitan Toronto and Region Conservation Authority, Downsview, Ontario.

Provision for protection of human life and property from the hazards of flooding and erosion is the basic mandate of the Authority and forms the major emphasis of the Watershed Plan. This mandate is expanded upon in four of the component Programs of the Watershed Plan; namely the Flood Control Program, the Erosion and Sediment Control Program, the Shoreline Management Program, and the Land Acquisition Program.

The Flood Control Program provides for the undertaking of remedial measures or the removal of hazardous structures through acquisition, and the application of regulatory measures to permit flood plains to carry out their primary function of passing flood flows in an unobstructed manner. The Erosion and Sediment Control Program is aimed at protecting life and property through corrective works as well as preventing future hazards through development control. The Shoreline Management Program is aimed at reducing erosion and flooding hazards along the Lake Ontario shoreline through protective measures and preventative regulatory controls. Working in conjunction with these three Programs is the Land Acquisition Program. The Land Acquisition Program is designed in part to bring flood plain and erosion hazard areas within the valleys and along the waterfront under public control.

Two additional component Programs recognize the relationship between urbanization, erosion and sedimentation and flooding. The Storm Water Management Program details cooperative action between the Authority and its member municipalities on water management problems with particular emphasis on rapidly developing areas, and on the preparation of master drainage plans to serve as the framework within which development occurs. The other Program, the Conservation Land Management Program, promotes conservation on private and public lands by providing reforestation, habitat improvement, stream improvements and a conservation land planning service.

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In addition to the mandate of protecting human life and property from the hazards of flooding and erosion, the Authority is also concerned with preserving and conserving natural areas and making the amenities of open space areas available to the public. In this regard, the other aspect of the Land Acquisition Program provides for the acquisition of conservation lands within the valleys and along the waterfront that are considered to be significant or environmentally sensitive.

The valuable ancillary use of conservation lands is the development of recreation areas for public use and enjoyment. The Watershed Recreation Program and the Lake Ontario Waterfront Development Program are designed to meet this need.

With regards to the two remaining component Programs of the Watershed Plan, the Heritage Conservation Program recognizes a special contribution that a historical perspective gives to the understanding of resource management. All of the efforts of the Authority in its conservation programs are dependant on community understanding and acceptance. The Community Relations Program establishes the means by which the Authority can communicate with the community and places special emphasis on legislators, municipal councillors, media and the school system.

This paper deals with the problems of storm drainage and the need for planned storm drainage systems at a comprehensive scale. This was subject of a report by the Urban Drainage Policy Committee as part of the Canada-Ontario Agreement on Great Lakes Water Quality.

One of the five policy proposals contained in this report was:

> "Municipalities in coordination with the conservation authorities, will be required to develop master drainage plans for all watersheds in their boundaries. The purpose of this policy is to foster master drainage

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> planning for rapidly developing municipalities to ensure that storm water drainage systems are developed in a manner compatible with watershed needs, to identify existing water quality and flooding problems and to avoid future problems."

This report also recognized the existing role that Conservation Authorities in Ontario play in the planning, development and operation of flood control, resource management and water conservation programs and went on to say:

> "Conservation Authorities are particularly well suited to play a major role in drainage planning because they have an overview of the entire watershed and they can play a coordinating role among the municipalities concerned."

As part of the Authority's Watershed Plan, new component Program for Storm Water Management implemented over time, and in cooperation with the local municipalities, hopes to address the problems of storm drainage resulting from urbanization in a planned, comprehensive fashion.

WATERSHED PROBLEMS IN THE METROPOLITAN TORONTO REGION

Basic changes in the hydrologic cycle, caused by development, underlie many of the drainage and water management problems in urban areas. Balanced hydrologic relationships developed over the course of time are quickly and significantly disrupted by the process of urbanization. As such, in the preparation of the Watershed Plan, major emphasis was placed on updating the hydrologic and hydraulic data base for the watersheds within the Authority's jurisdiction.

Some of the major watersheds within the Authority's jurisdiction are presently in an advanced stage of development, such as the Mimico Creek, the Don River and Highland Creek systems. Substantial new

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development is forecast for all major watersheds, however, and increased impacts may be expected on the water resources and water management programs of the Authority's region. Some of these impacts are worthy of discussion:

Land Use Changes

The majority of new development will occur in the middle zones, or reaches, of the watersheds. With the exception of the Humber River with its large headwater area, significant increases in developed area are envisaged for all other watersheds. The amount of land covered by the developing zone is expected to increase by about 300 km^2. (See Figure 1.)

Flood Flows

Flow rates and volumes are generally increased dramatically in proportion to the greater imperviousness and hydraulic efficiency of conventional urban systems. This is especially true for those smaller, more frequent storm events which, in the natural state, would be entirely absorbed by the soil. Increased flood flows result in larger bridge and culvert facilities, and may result in enlarged flood plains or floodways. Significant problems may be created in this way in headwater tributaries where the process of urbanization often requires modification of the existing watercourses.

Impacts along the Etobicoke and Mimico Creeks, Black Creek, the East and West Don, Highland Creek, and the upper portions of the Rouge River are particularly notable. The many small tributaries not shown at this scale are often the most severely affected. Figure 1 shows where anticipated flow increases are expected to be greatest. While some flood susceptible areas are of a relatively minor nature, the number of such sites downstream of the developing zone is significant. Figure 2 shows the locations of all flood susceptible areas identified

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in the Flood Control Program. Future development will magnify the impacts at existing flood susceptible areas and create additional damage sites if mitigative measures are not taken.

Erosion

Flooding and erosion problems, although not mutually exclusive, tend to be produced by different flow regimes. Whereas flooding is usually the result of infrequent severe flows, erosion usually results from cumulative effect of the more frequent smaller events that take place several times a year. It is precisely for these frequent flows that the impacts are greatest. The Authority presently implements a costly erosion control program designed to arrest present erosion problems. Unrestrained urban drainage development threatens to negate the effects of this program. The process of erosion ultimately results in enlargement of the stream as it seeks to adjust to the new flow regime, creating unstable banks, undercutting of existing structures and bridges, impairment of the water quality of small streams, and a loss of vital open space.

The location of identified erosion sites within the Authority's region, as shown in Figure 3, are generally downstream of the developing zone and thus are likely to be increasingly affected by upstream development.

Base Flow Reduction

Increased imperviousness results in less opportunity for infiltration into the soil, and consequently reduced base flow on many small tributaries. Here again the problem is greatest on small tributaries, where streams which once flowed all year may dry up entirely after development. Very little data are available on this problem, but this process generally results in reduced water supply, impaired water quality, and altered vegetation and wildlife habitat.

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Water Quality Degradation

Urban runoff contains many different pollutants washed off the land surface during rainstorms, thereby contributing to the degradation of urban streams. This might include the various forms of salts, pesticides and other chemicals used, as well as sediment, litter, and debris which accumulate in most urban areas. Recognizing that even under existing conditions the water quality of a particular stream may be poor, it is nevertheless beneficial to buffer the stream from the direct discharge of urban storm water and its associated pollutants.

Sediment removal during construction is a major source of water quality degradation and loss of fisheries habitat, and can affect other beneficial uses of urban streams as well. The relative magnitude of sediment removal for various types of land use compared with construction activity may vary by a factor of 100 or more. Ultimately, the sediment is redeposited along the lower reaches and lake outlet of the stream. Dredging to remove sediment deposits is presently required at several sites along the lakeshore. Figure 4 demonstrates the general deterioration of water quality in the Etobicoke Creek from its headwaters to its highly urbanized lower reaches.

Conclusion

In Ontario over 80% of the population lives in urban centres. By the turn of the century, the urban population of Canada will increase by 10 million people. Most of Ontario's share, which is one-third of the increase, will be in the Great Lakes basin. It is no overstatement to say that the Metropolitan Toronto region will be the focal point for the bulk of this increase. The urban growth that accompanies this population increase will bring substantial land drainage problems not only to the builder in the developing areas but to the built up areas where existing problems will be aggravated or new problems created.

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At present, there are many flooding, erosion, and water quality problems which may in part be attributed to unrestricted urban drainage. The amount of urban land within the Authority's jurisdiction is expected to grow from 550 km^2 to 850 km^2, an increase of about 60% of the whole. This will significantly affect many smaller watercourses in the developing zone, as well as some of the major valleys downstream.

Current flood plain management and erosion control programs are affected. On Highland Creek, for example, a heavily urbanized watershed, a continuous and expensive erosion control program is required to protect downstream private and public lands. A storm water management program would ensure that as much as possible, higher erosion-causing flows would be controlled at the source in developing watersheds.

The problems of managing and coordinating the various drainage schemes, plans, and programs in the developing zone will be made very difficult without a sound storm water management policy and master drainage plans dealing with all aspects of the problem. Under such a policy, overall cost savings in both major and minor drainage works can be achieved.

Finally, the attainment of general environmental and recreational improvement along urban streams requires a comprehensive storm water management program. There is a great potential for planned development of urban water resources, which is at present largely untapped. The use of natural drainage design concepts, linked open space/ recreational space along watercourses, and "Blue-green" technology offer, in the Authority's opinion, enhanced urban surroundings which help to re-establish man's traditional relationship to water and the natural environment.

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OPERATIONAL CRITERIA FOR STORM WATER MANAGEMENT DESIGN

Unquestionably the traditional approaches to storm water management are inadequate today. An environmentally aware public will no long permit higher damaging flows in already overtaxed downstream systems. The number of lawsuits in this regard is increasing and professionals have started to develop alternatives. In the United States for example, alternative drainage control strategies have been articulated into four basic objectives:

- existing natural drainage systems will be used as much as possible and left in a natural state;
- drainage channels will be gently sloping grassland swales as opposed to narrow deep ditches or trapezoidal channels;
- flow retarding devices such as retention ponds be used where practical to minimize increases in runoff volume and peak flow resulting from urbanization as it may affect erosion and flooding;
- drainage pipes and other flood control structures are used only where the natural system is inadequate.

Different jurisdictions have applied these objectives in various ways. Some have gone so far as to adopt blanket regulations which require all individual proposed developments to maintain peak flow rates from their sites at the level that existed prior to urbanization. This requirement dictates on-site retention. Concerns are being raised however about the composite hydrograph downstream. An alternative approach is to employ one regional retention device in lieu of several on-site facilities; this too can have an adverse effect on the composite downstream hydrograph if planning is not done on a watershed basis. Alternatively, some jurisdictions have implemented a regional drainage management scheme that would allow varying degrees of control

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in each of the watershed sub-basins, e.g. middle and upper portions would be required to retain peak flow to the predevelopment level while the lower portion would not have any retention in order to allow the downstream sub-basin to peak and recede prior to the upstream peaks arriving. An example of this in the United States is that funding for a four mile long flood control channel at the downstream end of a watershed was conditional upon the drainage from all the combined upstream development, old and new, not exceeding the designed capacity of this channel; this meant that a multi-jurisdictional body had to be set up to consider the impact of all new development on the composite downstream hydrograph.

The Authority, in considering the options for management of storm drainage in the future determined that there were three areas of concern which must be addressed in the establishment of drainage criteria.

1. The Minor System

The minor drainage system is composed of all those swales, gutters, catchbasins, storm sewers and outlets which carry the runoff from small, frequent storms. This is often referred to as the 'convenience' system, and is normally designed for storms with a return period of 2-5 years. The minor system usually discharges to the nearest stream or watercourse.

In most instances, downstream erosion and water quality impairment are worsened by these direct discharges from the minor system. Therefore, unless water quality, erosion or fisheries objectives are of no concern, detention facilities should be provided at or above all minor system outlets. Such facilities, along with other controlling devices along the minor system should be designed to control to predevelopment conditions, all flows up to and including the 2 year storm, as a minimum; this would include the great majority of small frequent summer storms.

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During the construction phase when surface erosion is at its greatest, temporary erosion control facilities should be constructed to minimize the discharge of sediment-laden runoff from the site. The use of berms, straw bales, and sediment traps are recommended.

2. The Major System

The major drainage system is composed of all the streets, walkways, channels, watercourses and ponds which carry the runoff from large, infrequent storms which overtax the minor system. This is referred to as the 'Flood Protection' system, and often falls under existing flood plain management programs. The Authority requires that all major drainage system components, irrespective of drainage area, must be designed to accommodate the greater of the 1 in 100 year or the Regional Storm post-development flows.

Where these components are man-made, such as streets and walkways, the major flow shall be accommodated without damage to structures or basements. When an open channel or a natural watercourse is utilized, all land that would be inundated by the major flow should be classified as hazard land.

The necessity and criteria for controlling flows in the major system will ultimately be determined through the master drainage planning process for the developing area. Consideration will be given to such alternatives as traditional drainage, zero increase in runoff, and controls on the minor system, or a combination of both. Existing downstream watershed flooding and erosion constraints should be recognized at this stage as well as environmental objectives established by the municipality and the Authority. The use of parkland, grassed swales and easements for conducting flow in the major system is beneficial, in terms of both quantity and quality of downstream runoff, and is strongly advocated by the Authority.

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Until master drainage plans are produced, the degree of control on the quantity or runoff from a proposed development should be:

(a) The post-development peak flow shall not be greater than the corresponding predevelopment peak flow for the 1 in 100 year storm.

(b) If the proponent wishes to pass post-development peak flows that are greater than the corresponding predevelopment peak flows for the design storm, he must be able to prove that the cumulative effect of such an increase will have no adverse impact downstream.

With certain defined overall restrictions contained in these guidelines, the Authority recommends flexibility and innovation in the development of new approaches. Storm water storage is accepted as a basic philosophy but is to be utlimately designed on a watershed basis and not on an individual development basis.

3. Natural Channel Design

In many cases it is necessary to modify and channelize small urban tributaries for servicing, flood control, or land use reasons. Usually, this is accomplished by constructing regular shaped, concrete lined flood channels which accelerate the passage of flood water downstream and do not contribute to the recreational and aesthetic attributes of the valley.

Where rechannelization is required, the Authority encourages the use of natural channel design concepts. The basic aim of natural channel design is to create a stream channel analogous to a configuration which would occur under natural conditions. In general, this means that the channel is constructed as a meandering low flow channel within a floodway.

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The bed slope in the low flow section is such that under normal flow conditions the channel bed remains stable; deposition is in equilibrium with erosion, and no changes result from normal flow conditions. In addition, curves and meanders are either protected or designed to remain stable under normal conditions.

The floodway is designed to carry high level flows, and is primarily intended to ensure safe discharge of major flood flows. It also serves to contain the low flow channel and protect it from encroachment, and to provide access and space along the stream for recreation or maintenance purposes.

In practice, it is often necessary to add stabilizing structures as critical points along the stream, such as:

- at structures, such as bridges, to ensure meanders do not shift and cause damage;
- on steep slopes along the floodway, to ensure bank stability;
- on some meanders, to help maintain the design configuration.

The advantages of natural channel design are:

(a) Natural flood plain widths may be reduced somewhat to fit the design floodway.

This can result in considerable land savings.

(b) Low flow characteristics of the stream are not altered.

Sediment loads, velocities, and hydraulic characteristics are maintained at natural levels for high frequency storm flows.

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(c) The floodway ensures safe disposal of high level flows.

The flood channel is well-defined, predetermined, and efficient and can provide for unforeseen future changes in hydraulic conditions.

(d) Downstream channels are protected.

As a consequence of point (b) above, the sediment load and hydraulic parameters entering downstream reaches are at natural levels. This prevents any artificially induced morphological changes to the stream, and maintains stream quality.

(e) The naturally designed channel continues to provide a substrate for wildlife.

Flora and fauna are maintained in the channel, which helps keep the water clean, productive, and aesthetically pleasing.

(f) The channel provides recreational space.

The natural design is inherently favourable for recreational use. Grassed banks, a meandering stream, close proximity, and easy access make such streams ideal for urban open space.

(g) Economy

The natural design can make use of existing stream patterns to a large extent, and does not involve the high cost technology of concrete or other traditional structural designs. This can result in a design which has a much lower initial cost than other methods. In addition, maintenance costs are low, since scour and deposition are minimized both at and below the new channel.

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IMPLEMENTATION OF STORM WATER MANAGEMENT

Storm water management is a preventative approach and is closely interrelated with detailed land use and sub-division design practice. Opportunities for implementing this approach are greatest if requirements are established in the earliest phases of development planning. The drainage of storm water in this respect is no different than the planning for a regional road system or sewage collection or water supply systems. The Authority can best direct its efforts therefore by working closely with the upper and lower tier municipalities to establish suitable policies and official plans statements establishing master drainage planning principles on various watersheds particularly those under pressure for development. If the principles of good storm water management and the resultant enhancement of overall stream quality becomes generally accepted at all levels, there will be a need to ensure that the preparation of storm water management plans are not left entirely to the discretion of the local municipality or to even an individual conservation authority. In this regard it is important that the Province of Ontario enunciate a clearly stated policy in favour of storm water management and the preparation of master drainage plans. Regional and local official plans should also indicate the overall contexts in which storm water management plans will be prepared. Upper-tier Official Plans should:

- foster a positive attitude rather than a reactionary one, by encouraging acceptance of the benefits of storm water management;

- as much as possible, standardize policies at the local municipal level to ensure some uniformity and consistency;

- give the legal effect to the implementation of storm water management.

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At the local level policies in Official Plans would provide overall guidelines when dealing with issues such as:

- zoning bylaws and amendments
- the subdivision of land
- drafting subdivision agreements
- site plan control bylaws under Section 35(a) of The Planning Act
- the preparation of master drainage plans
- acquisition of parkland
- etc.

The actual implementation of storm water management begins with the master drainage plan. There are three principle objectives that should be addressed as part of the preparation of master drainage plans:

(a) the establishment of basic watershed conditions;

(b) identification of drainage constraints (flooding or erosion or quality);

(c) evaluate storm water management options.

It is important to note that master drainage plans are the effective link between the planning policies and the actual design criteria. Planning policies would require that master drainage plans be prepared. Design criteria will then evolve from the master drainage planning and would be implemented during the preparation of secondary plans as part of the development approval process by municipalities.

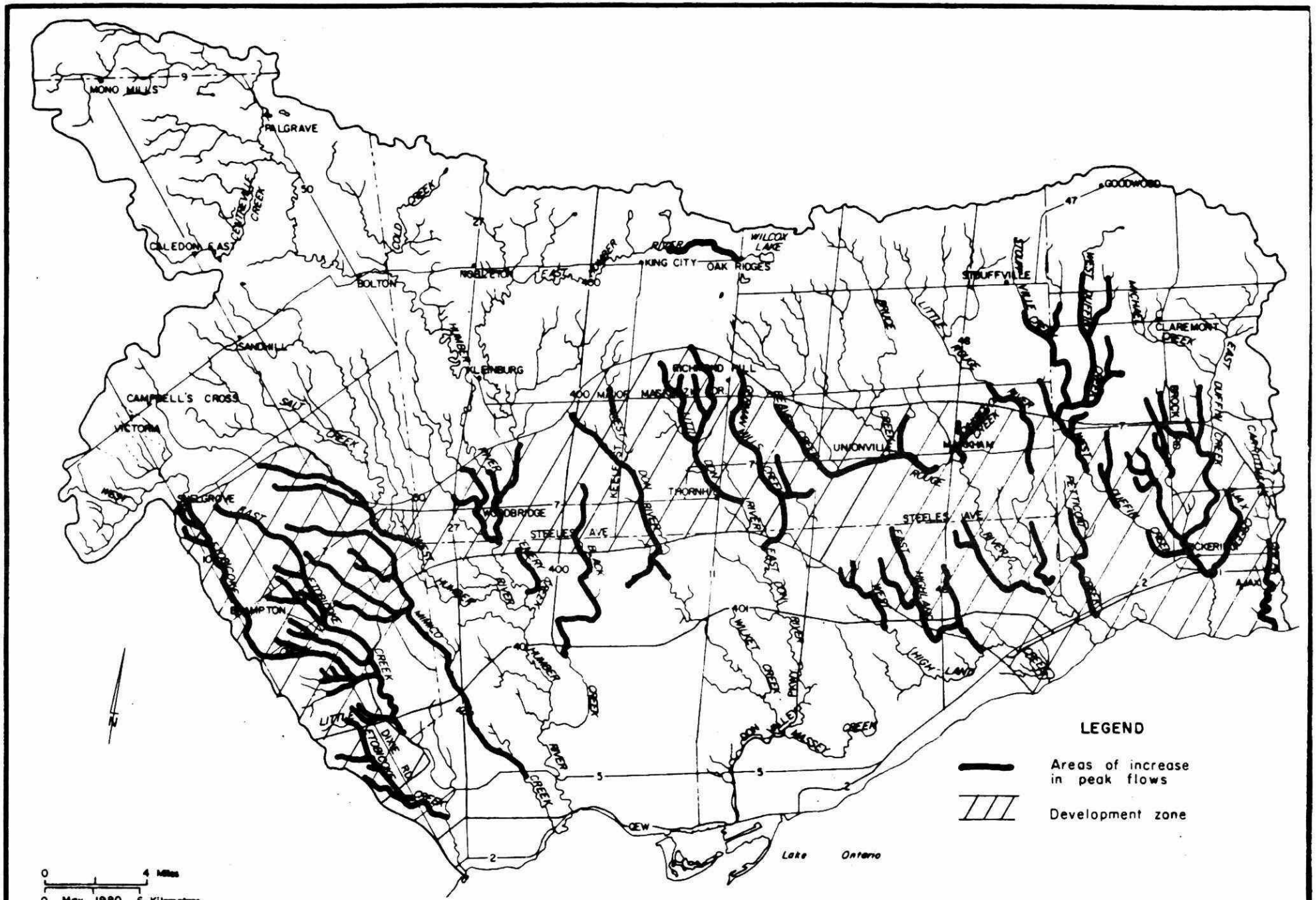
The Authority is of the opinion that it must play a key role in master drainage planning. It has available to it inventories of the opportunities and constraints as they exist along the watershed

/17...

including flood damage centres, erosion sites and areas where quality may be of concern. The Authority's Watershed Plan will provide a useful first step in this regard.

CONCLUSION

The preceding sections have described the establishment of a storm water management policy framework and performance criteria governing development proposals. Subdivision plans and site plans would then be considered by councils at both levels on the basis of the stated storm water management policies and criteria. These policies will then be applied in the development approval process in the same fashion, for example, policies dealing with parkland requirements, housing densities and the preservation of trees. The net effect of this process is that subdivision plans, bylaws, and all development agreements must of necessity incorporate provisions for storm water management and the implementation of the master drainage plan wherever practical and feasible. The master drainage plan itself would then have legal weight and both the municipality and developers would be legally bound to acknowledge it.



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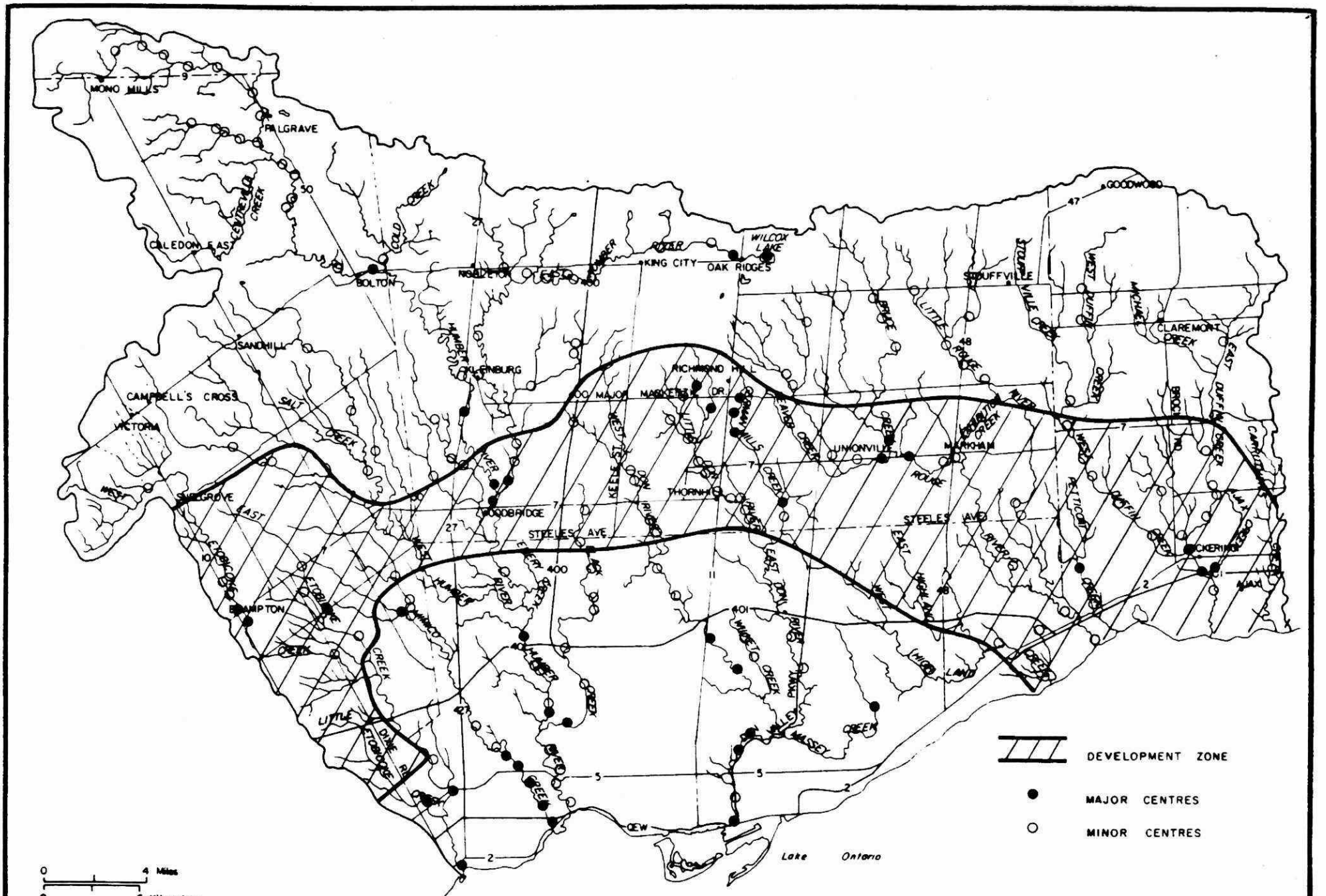
WATERSHED PLAN

STORMWATER MANAGEMENT PROGRAM

ANTICIPATED PEAK FLOW INCREASES

FIG. 1



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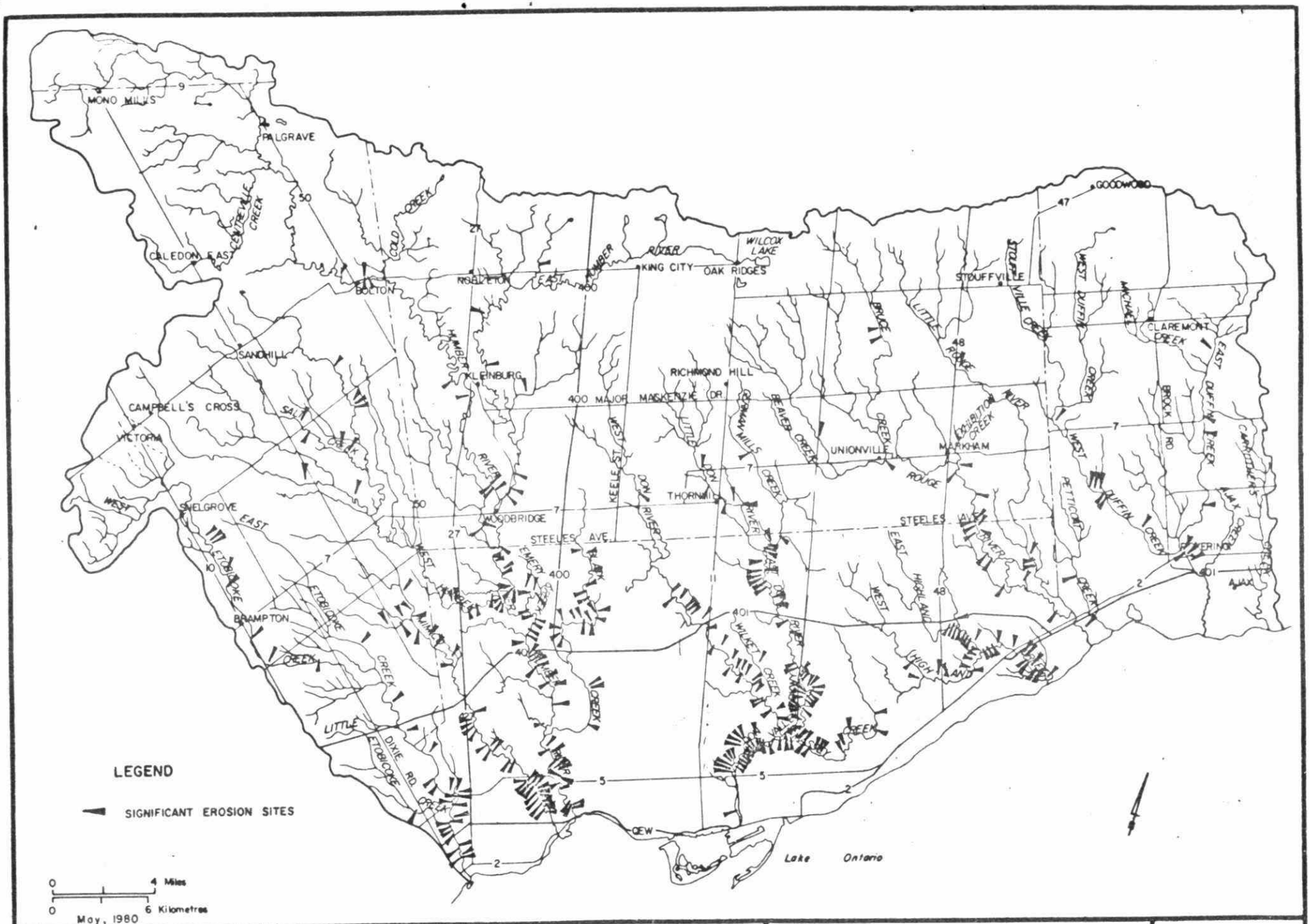
WATERSHED PLAN

STORMWATER MANAGEMENT PROGRAM

FLOOD SUSCEPTIBLE AREAS

FIG. 2



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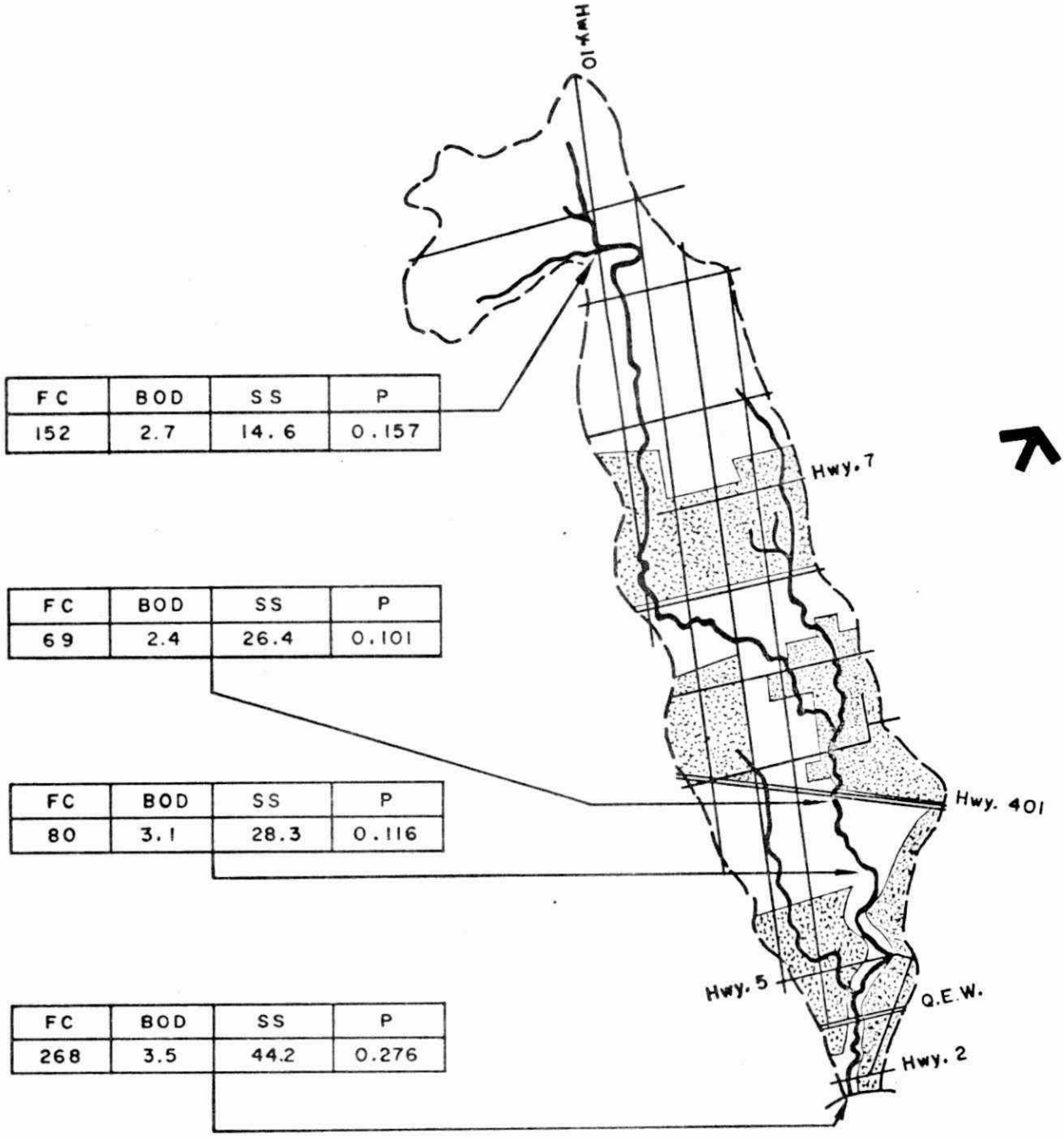
WATERSHED PLAN

STORMWATER MANAGEMENT PROGRAM

SIGNIFICANT EROSION SITES

FIG. 3



LEGEND

	Urban Areas
FC	Fecal coliforms (///100 ml.)
BOD	Biochemical oxygen demand (mg/ℓ)
SS	Suspended solids (mg/ℓ)
P	Total phosphorus (mg/ℓ)
	Developed Areas

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WATERSHED PLAN

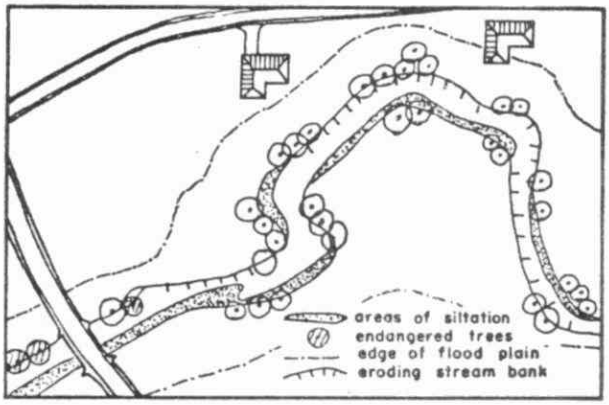
STORMWATER MANAGEMENT PROGRAM

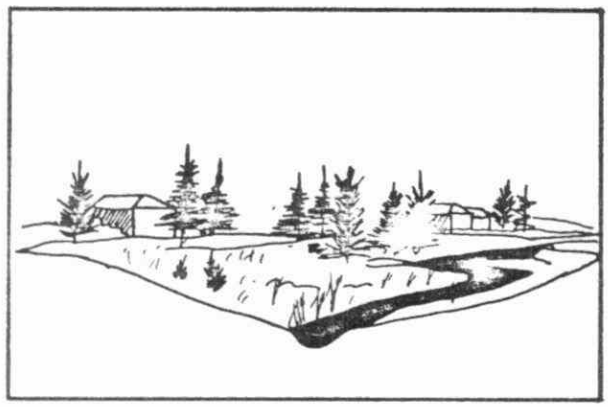
ETOBICOKE CREEK

CHANGES IN MEAN WATER QUALITY FROM HEADWATERS TO MOUTH

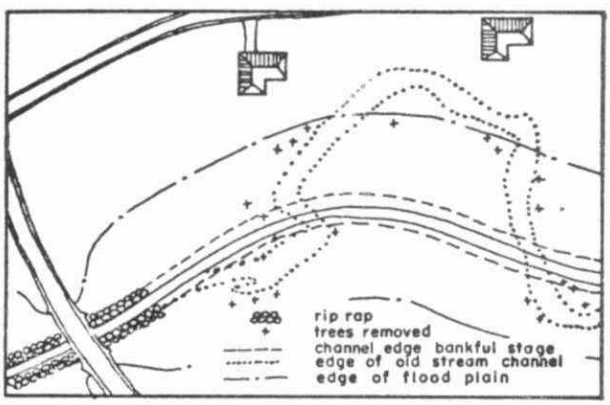
FIG. 4

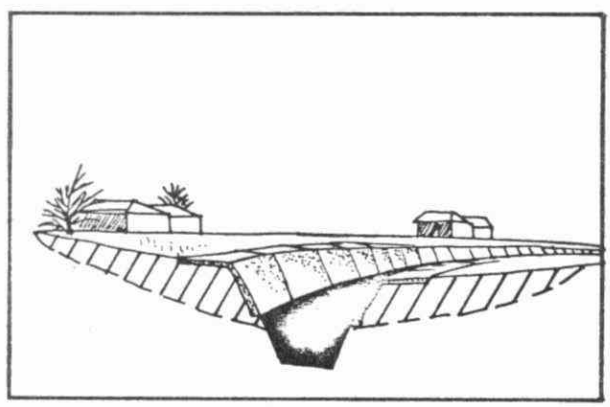
ENCROACHING URBANIZATION ON A
NATURAL STREAM CHANNEL



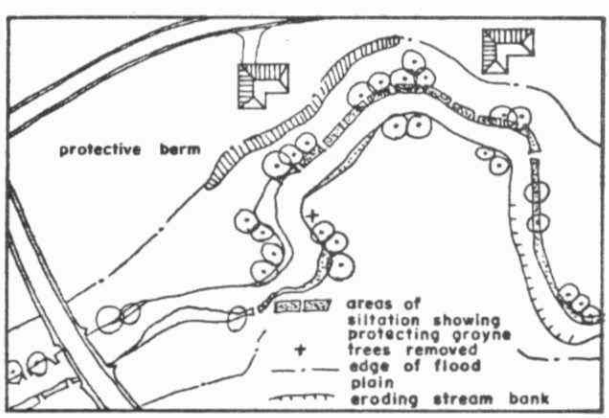


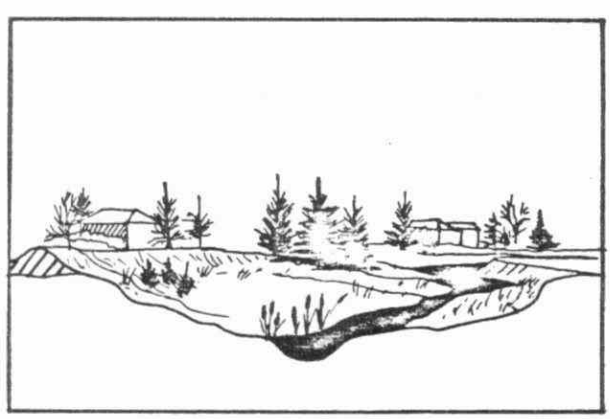
CONVENTIONAL FLOOD PREVENTION MEASURES





CONTEMPORARY FLOOD PREVENTION ALTERNATIVES USING
CONVIVIAL TECHNOLOGY AS A PART OF A COMPREHENSIVE
STORM WATER MANAGEMENT PROGRAM





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WATERSHED PLAN STORMWATER MANAGEMENT PROGRAM	NATURAL DRAINAGE DESIGN CONCEPTS	FIG. 5

LUNCHEON PAPER

OCTOBER 21, 1980

SKYLINE HOTEL, ETOBICOKE

BY

R. F. ALLEN, P. ENG.

OTHER CONSIDERATIONS BESIDES TECHNIQUES FOR STORMWATER MANAGEMENT

INTRODUCTION

GOOD AFTERNOON!

1. MY PARTICIPATION AS PART OF THIS SEMINAR IS THE RESULT OF A PERK OF OFFICE AND A RATHER EFFICIENT RAILROAD SYSTEM ENGINEERED BY A MICKEY-FOR-MAYOR CANDIDATE, ONE BILL WARWICK. FRANKLY, THE LOGIC OF THIS SITUATION ESCAPES ME.

2. SURELY BILL HAS ENOUGH PROBLEMS IN SCARBOROUGH, OVER STORMWATER, THAT HE COULD SPEND ALL HIS TIME THERE RATHER THAN CONDUCTING A SEMINAR SUCH AS THIS ONE. BUT THAT'S THE CHARACTER WE ARE DEALING WITH AND OUR ASSOCIATION CERTAINLY APPRECIATES THE DRIVE AND EFFORT HE HAS EXTENDED IN PREPARING THIS PROGRAM.

3. IN REVIEWING THE TWO-DAY PROGRAM OF THIS SEMINAR, I FELT THAT CERTAIN SIDE EFFECTS OF STORMWATER MANAGEMENT SHOULD BE ADDRESSED. TO ME, IT APPEARED TO BE AKIN TO THE OLDER METHODS OF PREVENTING CONCEPTION. THE COMMON APPROACH WAS THE CONDOM, DIAPHRAM, THE RYTHM METHOD OR COMPLETE ABSTINENCE. THUS, THE "PILL" WAS INTRODUCED ONLY TO FIND THAT THERE ARE CERTAIN HAZARDS CONNECTED WITH ITS USE.

4. IS THE "PILL" A PARALLEL TO THE INTRICACIES OF STORM-WATER MANAGEMENT? ALTHOUGH THE PARALLEL MAY BE A BIT OBSCURE, I WOULD LIKE TO DEAL WITH SOME OF THE CONCERNS THAT

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4. (Cont.)

SHOULD BE CONSIDERED AS PART OF THE MANAGEMENT PROCESS.

EDUCATION

5. A REVIEW OF SOME OF THE LITERATURE ON THIS SUBJECT REVEALS A VARIETY OF METHODS, MODELS, CONCEPTS AND TERMINOLOGY. ENGINEERS AND TECHNICIANS WILL HAVE A VARYING DEGREE OF UNDERSTANDING AND MEANING AS APPLIED TO THEIR WORK. WE WILL BE ABLE TO COMMUNICATE WITHIN OUR PROFESSION ON MODELS AND CONCEPTS SUCH AS: HYMO, ILLUDAS, SWMM, STORM OR MAJOR-MINOR AND ZERO RUN-OFF.

6. ULTIMATELY, COMMUNICATION MUST BE PASSED TO OUR POLITICAL BOSSES AND THE PUBLIC. WE MUST REMEMBER TO AVOID THE TECHNICAL JARGON AND GET DOWN TO GRASS ROOTS OR BASIC LANGUAGE OUTSIDE OUR TECHNICAL WORK PLACE. TO ILLUSTRATE THE POINT, THERE IS THE LACK OF UNDERSTANDING OF THE MEANING OF ZERO RUN-OFF BY THE PUBLIC, POLITICIANS AND THE MEDIA. IT IS OUR DUTY TO ENSURE A BASIC AND CLEAR UNDERSTANDING OF THE HOW AND WHY OF DESIGN TOOLS.

7. AS YOU HAVE LEARNED, THERE IS ANOTHER AREA OF EDUCATION THAT WILL BE ESSENTIAL TO THE FUTURE OF STORMWATER MANAGEMENT. EVERYONE MUST BE MADE TO UNDERSTAND THE DEGREE OF RISK AND RESPONSIBILITY INVOLVED IN DEALING WITH STORMWATER. NO MORE CAN WE ACCEPT THE PRIVATE INTERFERENCE WITH LOT GRADING FOR DRAINAGE, DOWNSPOUT AND SUMP PUMP OUTLETS, THE DECORATIVE BACKYARD PONDS AND THE PRETTY LITTLE WATERWHEEL WHICH OBSTRUCTS. THE GENERAL PUBLIC MUST BE EDUCATED AND ADVISED OF THE RISKS INVOLVED WITH TAMPERING WITH NATURE OR ALTERING RUN-OFF PATTERNS DESIGNED AND CONSTRUCTED FOR THEIR SAFETY.

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SAFETY

8. THE NEXT ITEM WHICH MUST BE LOOKED AT CAREFULLY, AND MORESO IN THE FUTURE, IS PUBLIC SAFETY IN THE DESIGN OF STORMWATER WORKS. CONSIDERING RETENTION, DETENTION AND DRAINAGE DITCHES, ETC., PROTECTION OF THE PUBLIC AND AESTHETIC TREATMENT MUST BE INHERENT IN THE FINISHED PRODUCT.

9. THE EFFECT OF A GRILL OVER THE ENDS OF A LARGE CULVERT TO PROTECT AGAINST ENTRY IN DRY WEATHER, IN MORE THAN ONE INSTANCE THIS SUMMER, HAS PROVEN TO BE A KILLER DURING RAIN STORMS.

10. THE CONVENTIONAL TRAPEZOIDAL DESIGN OF RETENTION AND DETENTION BASINS MUST BE REASSESSED TO PROVIDE GRADING AT THE SHORELINE TO FACILITATE RESCUE IN THE EVENT OF IGNORANT OR WILFUL TRESPASS.

11. UNLESS WE CONSIDER THE SAFETY ASPECT, THE BENEFIT OF GOOD DESIGN FOR STORMWATER FACILITIES WILL BE COMPLETELY NEGATED FOLLOWING THE FIRST SERIOUS ACCIDENT.

LAND

12. IT WILL BE QUITE OBVIOUS THAT SOME REMEDIAL OR INITIAL WORKS WILL REQUIRE MORE SPACE THAN WE HAVE TRADITIONALLY ALLOWED FOR STORMWATER. IN NEW DEVELOPMENTS, THE PLANNING ACT ALLOWS FOR A 5% DEDICATION OF LAND FOR MUNICIPAL PURPOSES. SUCH LAND DEDICATIONS HAVE, IN THE PAST, BEEN HABITUALLY UTILIZED FOR RECREATIONAL OR OPEN SPACE PURPOSES.

13. EVEN THOUGH ONE MAY COMPETE AGAINST RECREATION FOR SPACE FOR STORMWATER FACILITIES, THE ODDS ARE THAT THE DEVELOPER WILL HAVE TO PROVIDE ADDITIONAL LAND FOR RETENTION OR DETENTION PONDS, ETC. THEN WE WILL AGAIN BE FACED WITH

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13. (CONT.)

CRITICISM OF "GOLD PLATING" AT THE EXPENSE OF HIGHER HOUSING COSTS.

14. ONE SHOULD ALSO CONSIDER THE NEED FOR MORE LAND TO PROVIDE IMMEDIATE OR FUTURE SPACE FOR STORMWATER TREATMENT. WE ARE AWARE OF THE EFFECTS OF STORM RUN-OFFS ON RECEIVING WATERS AND IT IS ONLY A MATTER OF TIME BEFORE TREATMENT BECOMES MANDATORY.

15. ACQUISITION OF LAND AFTER THE FACT IS A MOST DIFFICULT AND COSTLY ADVENTURE. THE SPACE REQUIREMENT FACTOR MUST BE INCLUDED AND ADDRESSED EARLY IN DESIGN CONSIDERATIONS.

LEGAL

16. SINCE YOU HAVE A SESSION DEALING WITH DRAINAGE LAW IMMEDIATELY FOLLOWING THIS LUNCHEON WITH MR. DENNIS WOOD, I WILL NOT DEAL WITH THE "COMMON ENEMY RULE" OR THE "CIVIL LAW RULE". BUT RATHER, I WOULD TOUCH LIGHTLY ON ANOTHER SIDE WHICH IS TREATED VERY LIGHTLY.

17. I MENTIONED IT EARLIER. IT INVOLVES THE PRIVATE PROPERTY OWNER INTERFERING WITH A PRE-PLANNED AND REGISTERED LOT GRADING PLAN TO THE POINT WHERE HE CAUSES DAMAGE TO HIS NEIGHBOUR OR INTERFERES WITH THE DRAINAGE PLAN.

18. NOT ONLY ARE REAL ESTATE AGENTS NOT BRINGING SUCH COVENANTS TO THE ATTENTION OF THE BUYER, BUT SOME LAWYERS ARE EVEN NEGLECTING TO INCLUDE SUCH INFORMATION IN PROPERTY DEEDS.

19. IT IS A PROBLEM THAT MUST BE ADDRESSED IN THE SAME MANNER AS COMMON OR CIVIL DRAINAGE LAWS TO ENSURE MORE

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19. (CONT.)

RESPONSIBLE PUBLIC AWARENESS. I WILL LEAVE THIS ISSUE TO YOUR LEGAL SESSION.

CONCLUSION

20. YOU HAVE AND WILL BE ACQUAINTED WITH THE VARIOUS CONCEPTS FOR DEALING WITH STORMWATER MANAGEMENT. ALSO, YOU WILL BE GOVERNED IN YOUR DESIGNS BY PHYSICAL FACTORS, SUCH AS TOPOGRAPHY, RETURN PERIODS,IMPERVIOUSNESS, ETC.

21. WHAT I HOPE YOU WOULD ALSO CONSIDER ARE THE INDIRECT FACTORS WHICH SHOULD BE CONSIDERED IN YOUR DELIBERATIONS. I HAVE DEALT WITH A FEW SUCH AS PUBLIC EDUCATION, SAFETY, PROPERTY REQUIREMENTS, AND THE LEGAL ASPECT. OBVIOUSLY, TIME WILL NOT PERMIT ME TO DEAL WITH OTHERS SUCH AS COST BENEFIT, HAZARD AND FLOODPLAIN LANDS OR THAT REAL PROBLEM, ENVIRONMENTAL ASSESSMENT.

22. TO SUM IT ALL UP, I WOULD REPEAT THE MAXIM; "TIME SPENT IN PLANNING IS NEVER WASTED."

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